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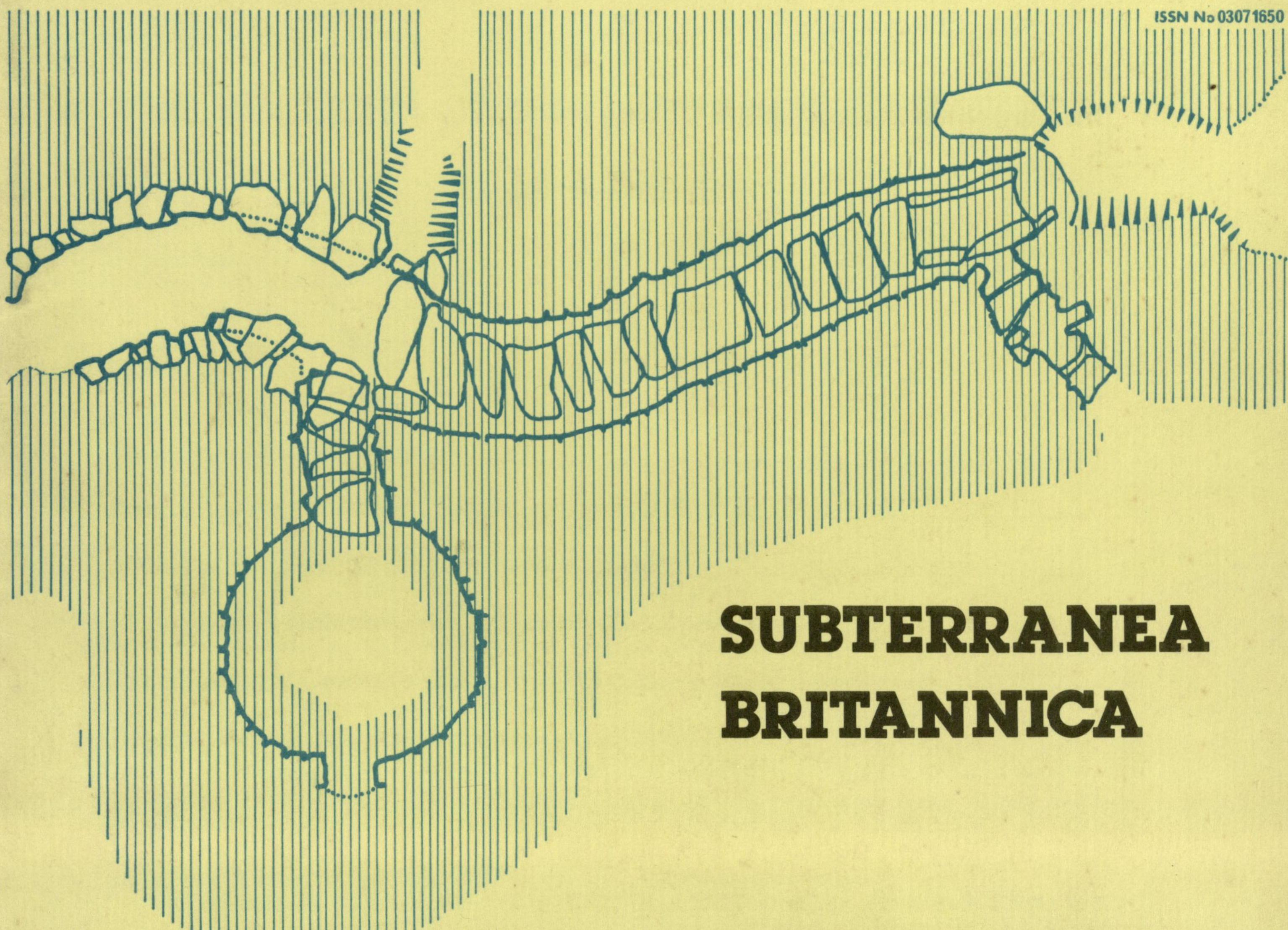
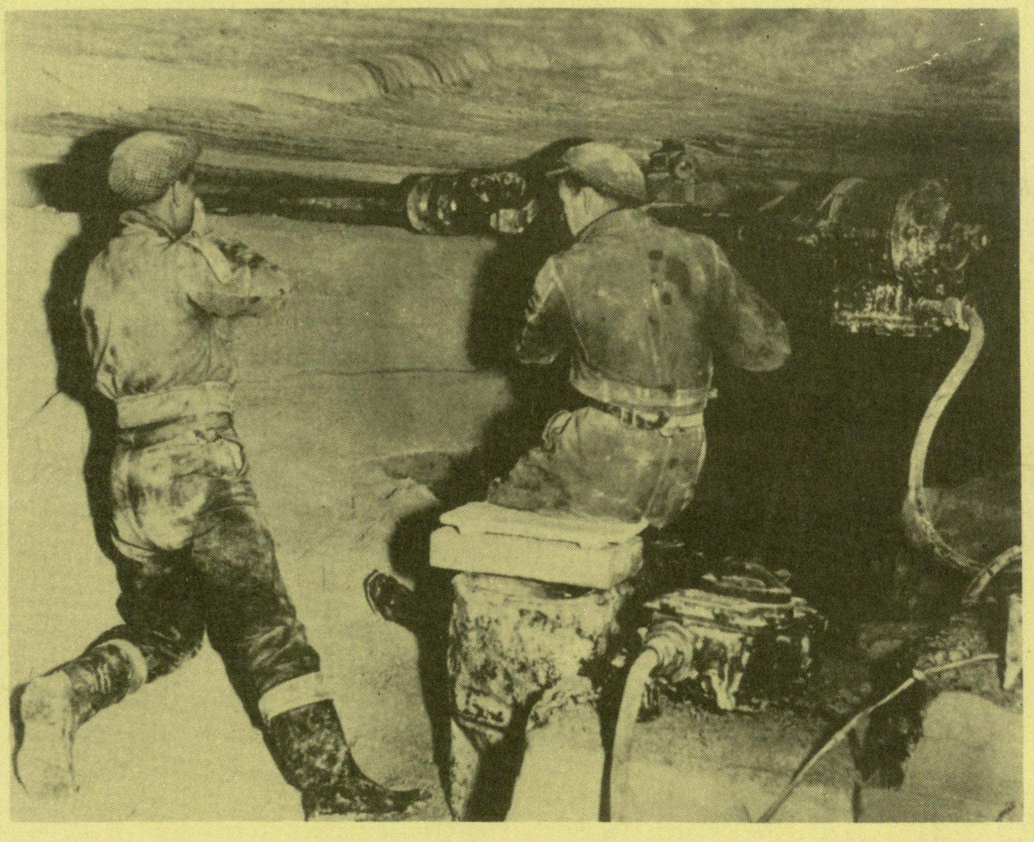


SUBTERRANEA BRITANNICA



Bulletin No. 28

THE BULLETIN OF SUBTERRANEA BRITANNICA

No. 28 – July 1992.

CONTENTS

Editorial – Malcolm Tadd .... page 2

Subterranean Gibralter – MS Rosenbaum & EPF Rose 3

A Well at Saltwood Castle, Kent – RF Le Gear 13

Mithraism: A Subterranean Religion – MC Black 16

The Enigma of Crocket's Holes, Newent, Glos. – David E Bick 21

Digging Bath Stone: An interim report – David Pollard 24

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This Bulletin is the official publication of Subterranea Britannica.

The Bulletin has been compiled and edited by Sylvia P Beamon and Malcolm Tadd with assistance from Martin C Black, Bernard O'Connor and Maureen Mahony.

Cover Photo: Picking with electric *Siskol* machine in Hartham Park Quarry, Wiltshire, during the 1950's (see "Digging Bath Stone").

EDITORIAL

While Bath City Council ponder on ''environmental impact'', its recent proposal to fill the stone mines at Combe Down are held in abeyance. The reason for filling the mines is that they are potentially and perhaps, in places, actually unstable.

There are additional advantages in filling mines. It enables the discrete disposal of ''inert'' materials such as pulverised fly-ash, produces employment, creates wealth for various contractors and consultants and above all demonstrates that the authorities are concerned with public safety and are ridding their localities of public nuisances.

Everyone knows that mines and underground structures are dangerous filthy places where the roofs always fall in (at least they do in attitude forming TV films), and from which children always need to be rescued.

The eliminator of underground structures, be he waste disposal contractor, road builder or property developer need fear no hindrance from listing, scheduling (you try to schedule an underground structure!) or public outcry. Even when the bat people object they can take heart that from certain newspapers comes the views that protection of bats is part of a socialist conspiracy.

At the moment there is talk of widening the badly planned M25. Should its route threaten to destroy the uniquely preserved medieval stone mines at Merstham and Bletchingley the planners can be confidant that there will be no opposing group for them to fight. Better destroy a medieval mine about which no one will object than a Victorian building or field of orchids about which there could be considerable indignation. And every underground structure destroyed without opposition gives the planner the confidence to perceive the next underground structure as an easy touch as far as destruction is concerned.

Finally the planner will probably find that no local underground society will raise a note of protest, but at times could find that such societies actually provide him with useful information for his destructive schemes.

Has your blood pressure soared?

If so it may be because you see underground sites as providing a special kind of archaeology. Not only is there evidence for past mining and underground building methods incorporated in their structures , but also, so are aspects of social and industrial history available for decoding in the form of wall and ceiling inscriptions, ruts rails and footprints in floors artefacts from primary and later usage of the structure and artefacts which have found their way from the surface. Unlike main stream archaeology we are only beginning to make best use of the underground record

It has to be faced that most structures are preserved because they are essentially pretty and enhance the visual quality of the landscape. Underground structures enhance the quality of life because they provide almost the only escape from modern life particularly its noise. Don't let them disappear.

If you know of underground structures under threat please contact me.

ARTICLES FOR THIS JOURNAL

The Bulletin of Subterranea Britannica is the only journal solely devoted to matters concerning man-made and man-used underground space. It therefore offers opportunities for publishing articles not suited to the policies of other journals and caving magazines.

Articles (typescripts) from anyone will be considered but note that line drawings should be clear, should have good legends and contain a scale where necessary. North signs should be at top right hand corner.
PC and Apple Mac computer discs are NOT welcome (viruses!) but 3inch discs as used for locoscript on Amstrad PCW machines will be VERY WELCOME.

SUBTERRANEAN GIBRALTAR: THE TUNNELS AND CAVES OF THE ROCK

M S Rosenbaum and E P F Rose

(Departments of Geology, Imperial College and Royal Holloway & Bedford New College, University of London)

Geographical and Geological Setting

Gibraltar is a rocky peninsula rising to a maximum height of 424 metres which juts southward into the Mediterranean Sea from southern Spain (Fig.1). Its historical role as a fortress guarding the maritime passage east-west through the Straits connecting the Mediterranean Sea with the Atlantic Ocean and narrowly separating the European and African continents is well known. Its limited land area of some 5.8 square kilometres and its role as a fortress have combined to make the demand for underground facilities a pressing local problem, and stimulated almost uniquely imaginative solutions to maximise protection and survival of both civilian and military personnel. Thus tunnels through the Rock have been excavated intermittently from the late 18th Century almost to the present day, and now total an incredible 50 kilometres within the Rock itself whose Main Ridge area measures only two and a half by one and a half kilometres.

For reasons of military security, ready access to the tunnel systems has generally been restricted to Service personnel, and details of tunnel construction and scope have not been widely publicised. However, parts of the system are now increasingly accessible to visitors, and the Gibraltar Museum has recently published the first booklet documenting the history of tunnel development (Rosenbaum & Rose, 1991b). It is therefore timely to summarise some of the main features here.

The rock itself is mostly of Gibraltar Limestone, a formation of Jurassic age some 600 metres thick, underlain and overlain by thinner "Shale" formations (which include mudstone, siltstone, sandstone and thinly bedded limestone) (Figs.2,3). These bedrock units are in turn overlain by much more recent superficial sediments, of Quaternary age, notably scree breccias and sands which form slopes flanking the Rock. The very first detailed geological map of Gibraltar to be published

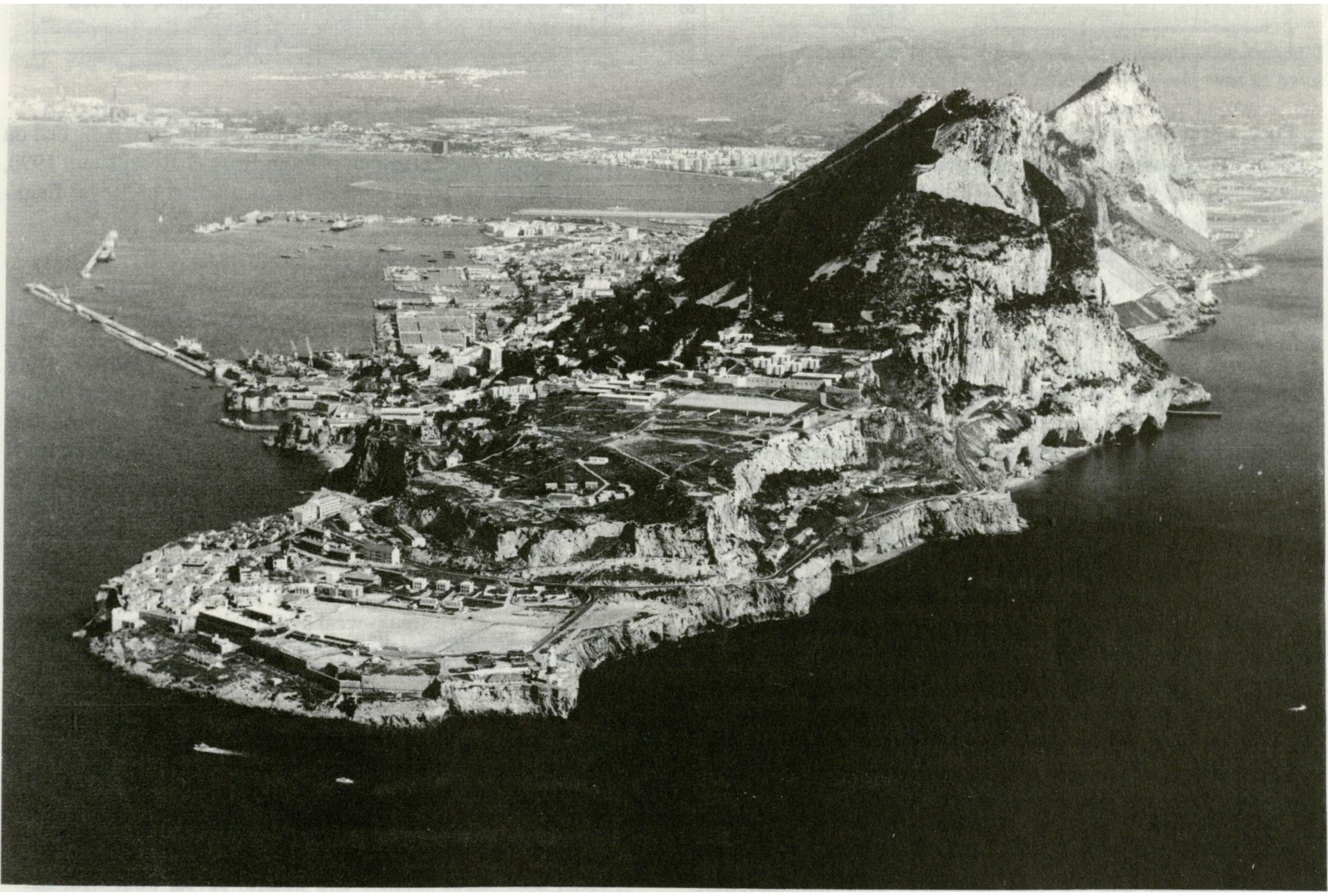


Fig.1. View of Gibraltar from the southeast (From Rose & Rosenbaum 1990, courtesy of the Institution of Royal Engineers).

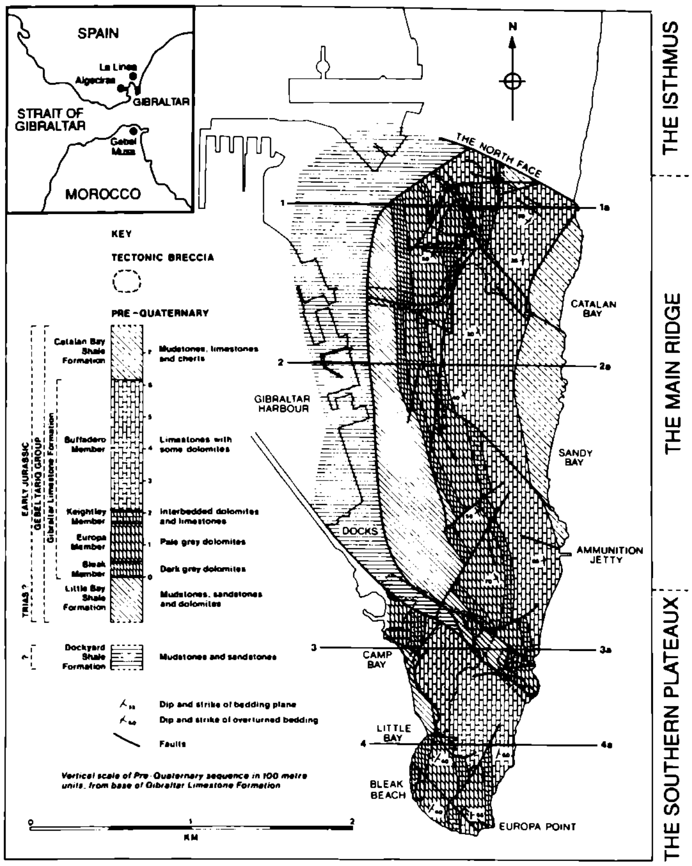


Fig.2. Map of solid (bedrock) geology of Gibraltar. (From Rose & Rosenbaum 1990, amplified 1991a, reproduced by permission of the Institution of Royal Engineers).

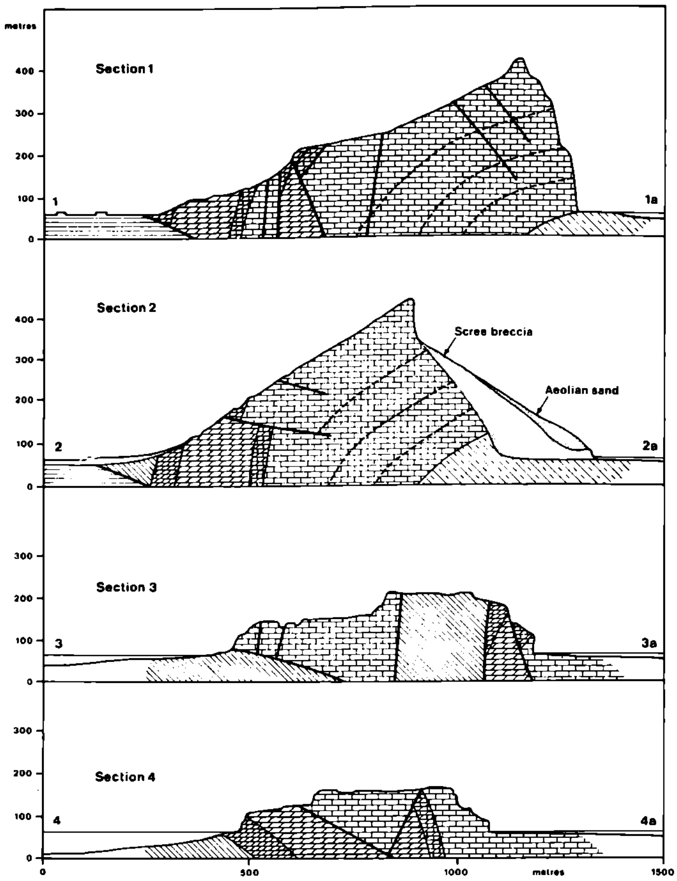


Fig.3. Geological cross-sections along the lines indicated on Fig.2, with same ornament. (From Rose & Rosenbaum 1990, reproduced by permission of the Institution of Royal Engineers).

appeared only recently (Rosenbaum & Rose, 1991a), together with a review of geological research on the Rock (Rose & Rosenbaum, 1990), a detailed field guide (Rose & Rosenbaum, 1991a), and a concise geological overview (Rose & Rosenbaum, 1991b). Full details of the geology will not therefore be considered further here except for the following aspects which are of relevance to subterranean Gibraltar.

(1) The Limestone is a strong rock. Except where weakened by faults or by closely-spaced joints, excavations within it can be unlined. Yet it provides a hard, durable rock which can be cut and shaped by metal chisels and drill bits with relative ease. This is due to the comparatively non-abrasive hardness of the calcite and dolomite minerals of which the Limestone is composed. Indeed this facilitated the use of the rock as a building material early in the history of Gibraltar. By contrast, the Shales contain very weak beds, some of which disintegrate on exposure to moisture and air, and have thus inhibited tunnelling activity.

(2) The Limestone is a soluble rock. In consequence, it is now riddled with caves, of which at least 143 are known

Water can be observed dripping from rock fractures in some of the tunnels throughout the year. Much of this is due to rainfall slowly percolating down through rock fractures, but some is saline and is likely to be associated with leaks from overlying reservoirs holding the sea-water supply which supplements the potable water supply system on Gibraltar. The control of groundwater pressures in the vicinity of tunnels both during and after construction exerts a major influence on tunnelling technique. A particularly difficult area was located in the south-west of Gibraltar where, due to their impermeable nature, the mudstones within the Shales were able to maintain a relatively high water pressure within the Gibraltar Limestone beyond. In addition, a major fracture zone known as the Great Main Fault here bisects Gibraltar and together these effects made tunnelling almost impossible in the vicinity.

Subterranean Gibraltar therefore comprises voids of two sorts, man-made tunnels and natural caves, both with features of especial interest, the former sometimes developed from the latter.

Tunnels

The oldest visible evidence of a man-made underground chamber is associated with the collection of groundwater at Nun's Well, near Europa Point at the southeast tip of the peninsula, a historical site now under the protection of the Gibraltar Government. This early Moorish cistern, dating probably from the 8th Century or possibly even earlier from Roman times, collects water from a rock fracture that drains through the Gibraltar Limestone of the higher Windmill Hill Flats plateau extending north towards the Main Ridge. Details of the site have been recorded by Palao (1979).

Such early excavations were small, isolated, and relatively insignificant apart from the Moorish Castle reservoir (excavated under Spanish rule pre-1704, with a capacity of some 5.7 million litres) which provided the first centralized water supply for the town. Five distinct periods of major and significant tunnelling works were to follow:-

(1) 1782-1800, the early tunnelling period, from the Great Siege of 1779-83 when tunnelling first began until about 1800 when the Galleries overlooking the Isthmus forming the North Front were completed (Fig.4).

(2) 1880-1915, when, after a long gap in which there had been no tunnelling, the Admiralty, the Army and the City Council all began to go underground to excavate magazines, communications tunnels and water reservoirs.

(3) 1933-1938, when construction of reservoirs for water storage, and more particularly construction of air raid shelters and underground hospitals, caused much tunnelling activity.

(4) 1939-1945, when the greatly increased war garrison required new accommodation space, and space for food, equipment and ammunition.

(5) 1946-1968, when the existing tunnels were linked together in a more efficient manner and additional storage chambers and reservoirs were hewn out of the Rock.

In total some 50 kilometres of tunnels and chambers now honeycomb the Rock (Fig.5), but since little more than one thousandth part of the Rock has been removed, there need be little anxiety that it has been riddled to the point of `collapse'!

The early tunnelling period is well documented in detailed accounts given by Goodwin (1928), Eley (1957) and Palao (1979). Early fortifications overlooking the North Front were trenches cut in the solid rock or built up with masonry: the King's Lines constructed prior to British capture of the Rock in 1704, the Prince's Lines excavated between then and the siege of 1727, and the Queen's Lines during the Great Siege of 1779-83.

It was during the Great Siege that an attempt to mount guns so as to bring flanking fire on the enemy led to tunnelling behind the North Face of the Rock overlooking the Isthmus by Sgt. Major Ince and the Company of Soldier Artificers (a parent unit of the Corps of Royal Engineers). The original tunnel, now part of the Upper Galleries network, was to have been just a passageway leading to a promontory known as the Notch. However, with the use of tunnelling techniques based on gunpowder, the miners found the atmosphere in the excavation almost unbearable due to fumes from blasting (they relied on gunpowder charges for loosening the rock, and the strength of their arms and skill with sledgehammer and crowbar for its excavation). A ventilation hole was therefore blasted sideways into the open air. The advantage of mounting a gun there was immediately apparent, so the plan was changed. The tunnel became a gallery, and in the end 12 cannon embrasures were made within it.

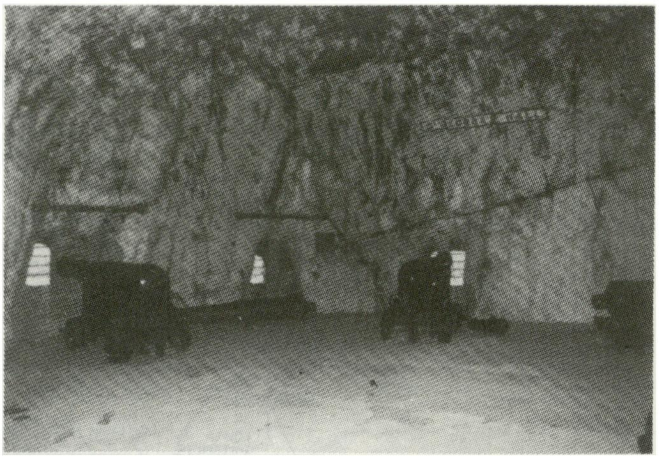


Fig.4. St George's Hall: part of the Upper Galleries network of tunnels constructed during the early tunnelling period, (Courtesy of the Gibraltar Tourism Agency Ltd.).

St. George's Hall and the neighbouring Cornwallis Hall (both completed 1784-5) added ten more embrasures, and a series of tunnels was developed to provide underground communication between the surface defensive walls and trenches (known as the Lines). At the northern end of the Kings's Lines is a natural cave which became the focal point of tunnelling activity, acquiring the name of Star Chamber. The system of galleries was effectively complete by 1800 and military tunnelling then ceased until the end of the 19th century.

The second period began in 1880 when the railway tunnels in Camp Bay north to Rosia Bay bordering the southwest coast of the Rock were excavated to provide quarry access. Then in 1895 the Army carried out underground works to extend some of the caves known as Genista, beneath Windmill Hill (the more northern of the two southern plateaux), and convert them into the Beefsteak Magazine. The caves had earlier been explored and surveyed by J Frederick Brome, governor

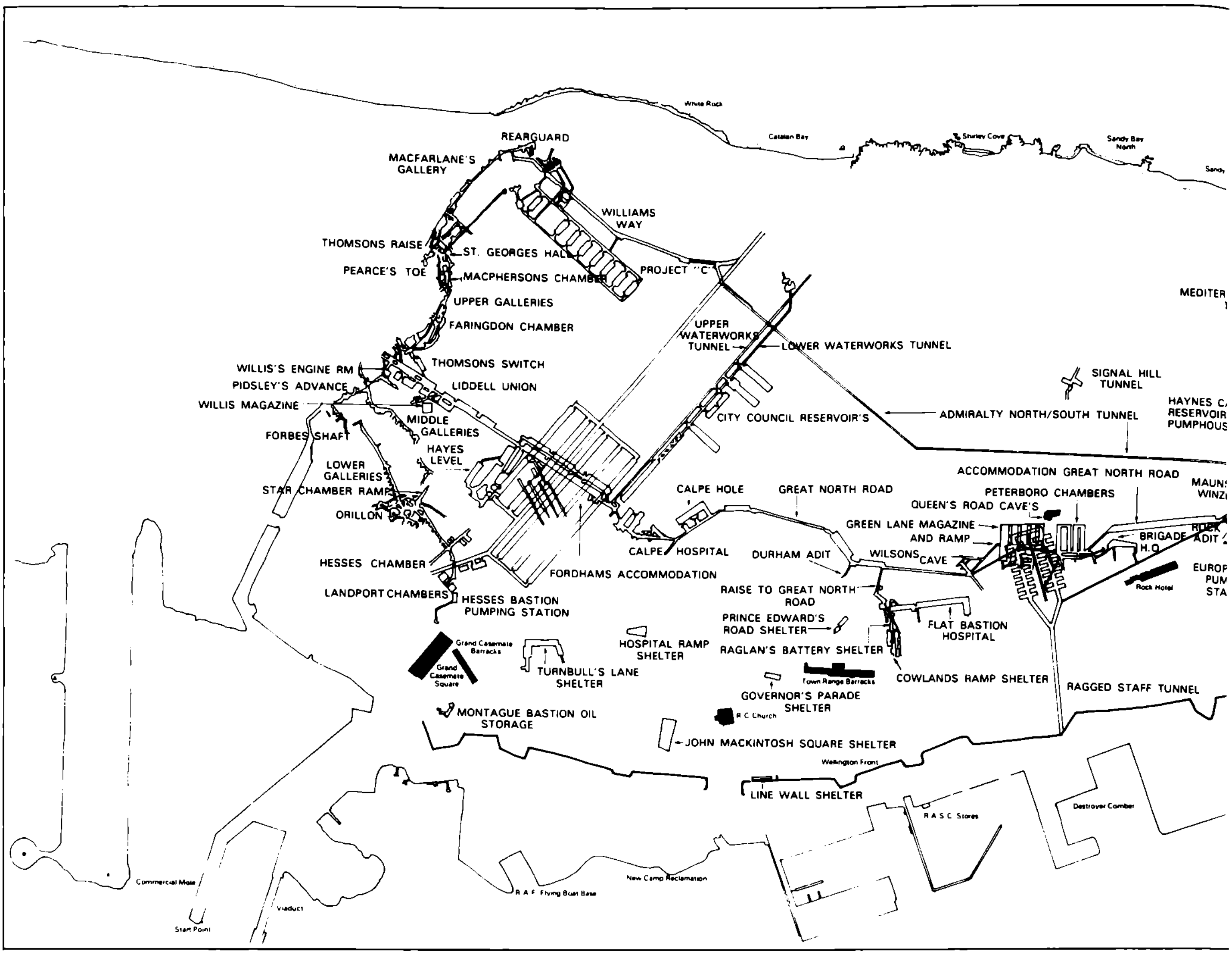


Fig.5. Gibraltar tunnel plan. (From Ramsey 1978, courtesy of the publisher and of the Commander British Forces Gibraltar; coastline as at 1945. ©British Crown copyright 1991/MOD. Reproduced with the permission of the Controller of Her Britannic Majesty's Stationery Office).

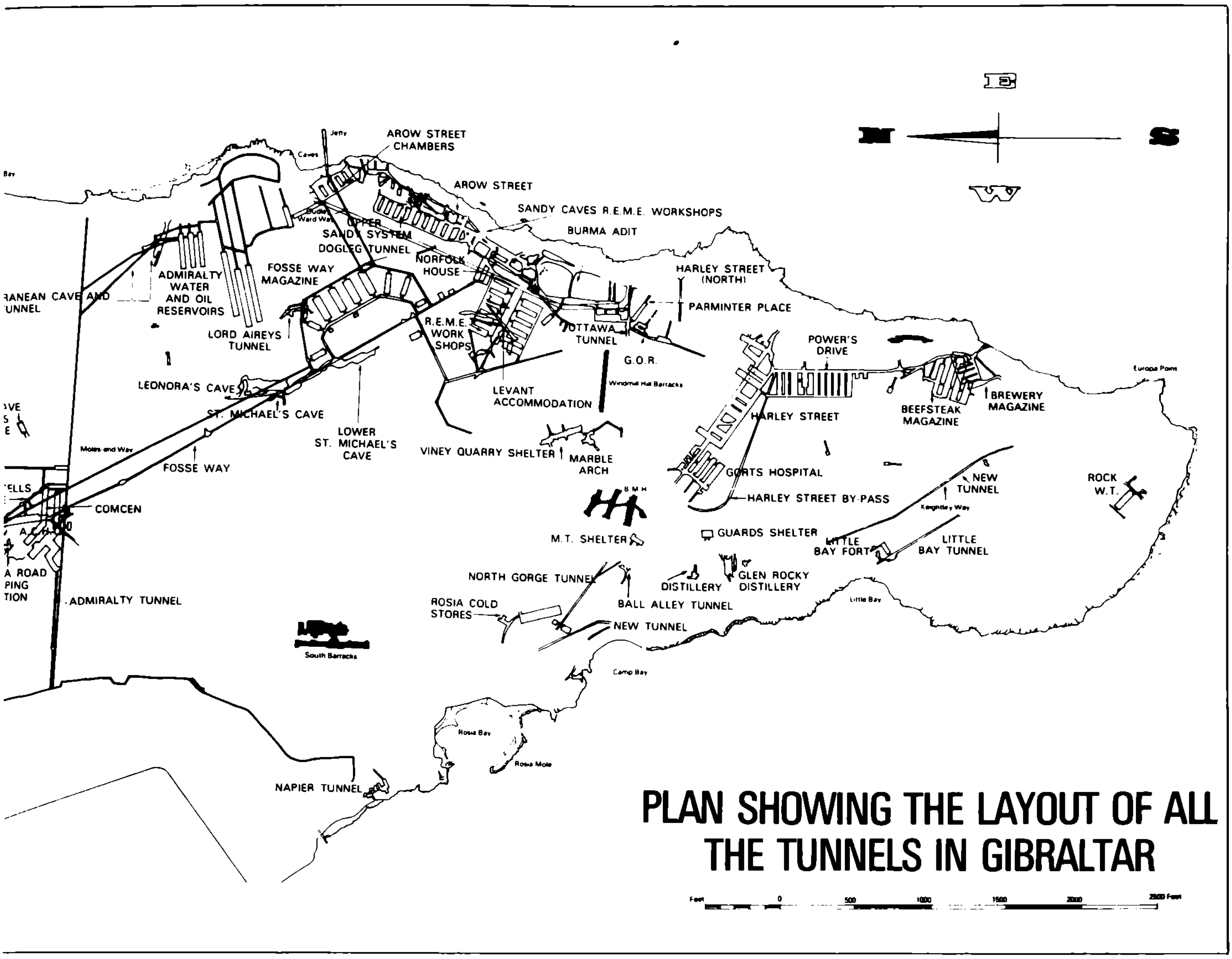
of the military prison, with the assistance of its inmates (Fig.6 gives an example of his handiwork), and the name commemorates his efforts (*Genista* being the Latin botanical name for the yellow-flowering shrub called Broom in English).

Soon after this, in 1898 to 1899, the Admiralty's contractors (the British construction company Cochranes Ltd.) drove the Dockyard Tunnel east through the entire mass of Gibraltar to Sandy Bay in order to develop the quarries there. Additionally the continuing pressure on building space and the need for security led the Admiralty in 1901 to begin a four-year project to convert the natural Ragged Staff Cave bordering the (western) harbour area into a magazine. The approach tunnel had to be fully brick-lined when completed since it passed through the uncemented superficial (Alameda) sands which covered the western flank of the Rock.

The construction of the modern water system commenced with the works of 1898 to 1900 to excavate four water reservoirs from the solid Limestone rock under the west side of Gibraltar (Fig.7). Each of these was 60 metres long, 15 metres high and had an average width of 6 metres, with a total capacity of 23 million litres (Anon., 1970). The excavations were lined with bricks and thus rendered impervious. These reservoirs were fed with water collected from a rocky area on the upper slopes on the north-west corner of the Rock which was cleared of its natural vegetation and all crevices filled with concrete.

As demand for water increased, further sources of supply were required and a scheme, an entirely original idea conceived by the then City Engineer of Gibraltar, was carried out consisting of forming a catchment area of 4 hectares on the east side of the Rock and driving a tunnel almost one kilometre long from east to west in order to form a channel with which to convey the water to the newly excavated reservoirs on the west side. The first catchment was constructed in 1903 on the sandy slope on the east side of the Rock where the average inclination was 3 to 2, i.e. about 34 degrees to the horizontal (Fig.8).

Between 1911 and 1914 another reservoir of 9 million litres capacity was constructed and the catchment area increased by a further 6 hectares.



PLAN SHOWING THE LAYOUT OF ALL THE TUNNELS IN GIBRALTAR

The 1930's marked the third period of tunnelling as the political situation and the ever increasing strength of Nazi Germany prompted further underground activity; in particular the construction of air raid shelters and underground hospitals beginning about 1936. About the same time the City Council was enlarging its water storage capacity by a further 23 million litres. Between 1933 and 1938 they built Water Reservoirs Nos.6 to 9 leading off from Waterworks Tunnel, and made a start on No.10, the one at the far eastern end. (When war broke out the Garrison took over No.10, and erected within it a two storey brick-built storehouse and barracks which were then occupied by 4th Battalion The Black Watch for part of the War. The reservoir reverted to its intended use in 1945.)

By 1939 the total length of tunnels in the Rock of Gibraltar was just 10 kilometres, having been increased from 8 kilometres length just prior to the First World War (Palao, 1979, p.59). The fourth period of tunnelling then saw a dramatic increase in tunnel length (Cotton, 1948; Wilson, 1945). After the evacuation of the British Expeditionary Force from Dunkirk and the collapse of France, with the entry of Italy into the War, and a powerful Germany dominating Europe, the strategic importance of Gibraltar was intensified. The Garrison had to be increased in size and strengthened, including preparations made to deal with possible siege conditions. The problem was urgent and vital; space became even more valuable; stores, food, and equipment had to be built up, and protected, and siege accommodation was required for the troops.

A tunnelled system would meet these needs, and would give full protection from the then known types of air attack, as well as from sea and land bombardment.

In October 1940, the first Tunnelling Company of Royal Engineers arrived and excavation commenced, as described in some detail by Haycraft (1946). Three more Companies were to join them. Although in the initial stage development started at the north end of the Rock, the most pressing need was for the provision of new accommodation for the rapidly growing garrison. The obvious starting place was the existing galleries, and the peace of Willis's Gallery was broken after a lapse of almost exactly 150 years. The embrasures in Willis's, Queen's and the Upper Union Galleries became barrack rooms fitted with double bunks, and from the top end of Willis's a new tunnel was begun, which first linked to Water Reservoir No.10, and then continued south as the Great North Road. Further south this became Fosse Way and it eventually reached the sea at the other end of the Rock. It was realised that the Main Base Area should be on the south-east side of the Rock, protected and hidden from Spain, but facing the Mediterranean.

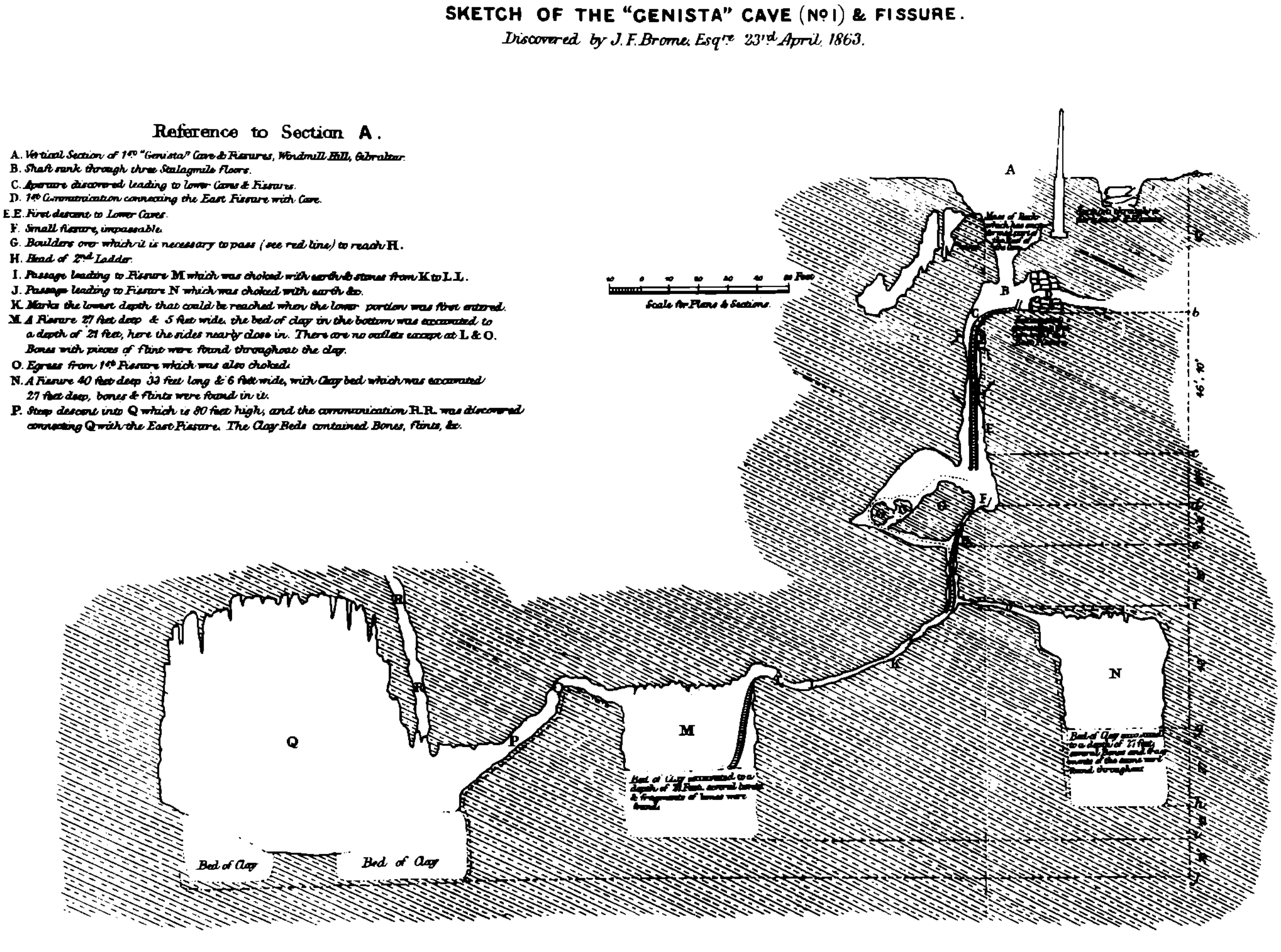
By the end of the War there were something like 40 kilometres of tunnels cut in the Rock, and during this time about one million cubic metres of rock had been removed.

During the final, post-war, period of tunnelling the Army tunnellers were engaged on a variety of storage area developments such as Project `C' for fuel storage as well as minor maintenance tasks. Two more water reservoirs, providing an additional 9 million litres capacity, and a further 4 hectares of catchments and auxiliary channels were constructed between 1958 and 1961. Together with the Moorish Castle reservoir, these brought the total to 13 reservoirs with a combined capacity of 72 million litres. In 1960 construction of Keightley Way Tunnel commenced, followed by Dudley Ward Way in 1963, but the last major project was to be the construction of Molesend Way between 1965 and 1967.

By April 1968 the Tunnelling Troop had been disbanded and all remaining tunnellers left Gibraltar on posting to other Units. The responsibility for the maintenance of the existing tunnels (Fig.9) then fell upon the Gibraltarian Ministry of Works and the British Ministry of Public Building and Works (later to become the Gibraltar Public Works Department and the Property Services Agency of the Department of the Environment respectively).

Caves

Gibraltar is honeycombed by natural caves as well as by Sapper tunnels. 143 principal caves have been distinguished to date situated above present day sea-level, and more are known to occur below. The positions of entrances above sea-level have been recorded on an unpublished map by G L Palao, as Surveyor to the Gibraltar Cave Research Group. Many of the caves have been subject to very detailed topographic survey, and from these surveys maps and cross-sections have been prepared on scales ranging from 1 inch: 4 feet (1:48) to 1 inch: 25 feet (1:300), predominantly the former scale. Detailed but unpublished descriptions also exist in manuscript for many of the caves. The Gibraltar Cave Research Group has maintained an active interest in the caves; its survey records are kept by George Palao with a view to eventual publication.


SKETCH OF THE "GENISTA" CAVE (No 1) & FISSURE.

Discovered by J. F. Brome, Esqre 23rd April, 1863.

Reference to Section A.

A. Vertical Section of 1st "Genista" Cave & Fissures, Windmill Hill, Gibraltar.
B. Shaft sunk through three Stalagmite floors.
C. Aperture discovered leading to lower Caves & Fissures.
D. 1st Communication connecting the East Fissure with Cave.
E.E. First descent to Lower Caves.
F. Small fissure, impassable.
G. Boulders over which it is necessary to pass (see red line) to reach H.
H. Head of 2nd Ladder.
I. Passage leading to Fissure M which was choked with earth & stones from K to L.L.
J. Passage leading to Fissure N which was choked with earth &c.
K. Marks the lowest depth that could be reached when the lower portion was first entered.
M. A Fissure 27 feet deep & 5 feet wide, the bed of clay in the bottom was excavated to a depth of 21 feet, here the sides nearly close in. There are no outlets except at L & O. Bones with pieces of flint were found throughout the clay.
O. Egress from 1st Fissure which was also choked.
N. A Fissure 40 feet deep 33 feet long & 6 feet wide, with Clay bed which was excavated 27 feet deep, bones & flints were found in it.
P. Steep descent into Q which is 80 feet high, and the communication R.R. was discovered connecting Q with the East Fissure. The Clay Beds contained Bones, flints, &c.

Fig.6. General cross section through part of the Genista cave system. (From Busk, 1869).

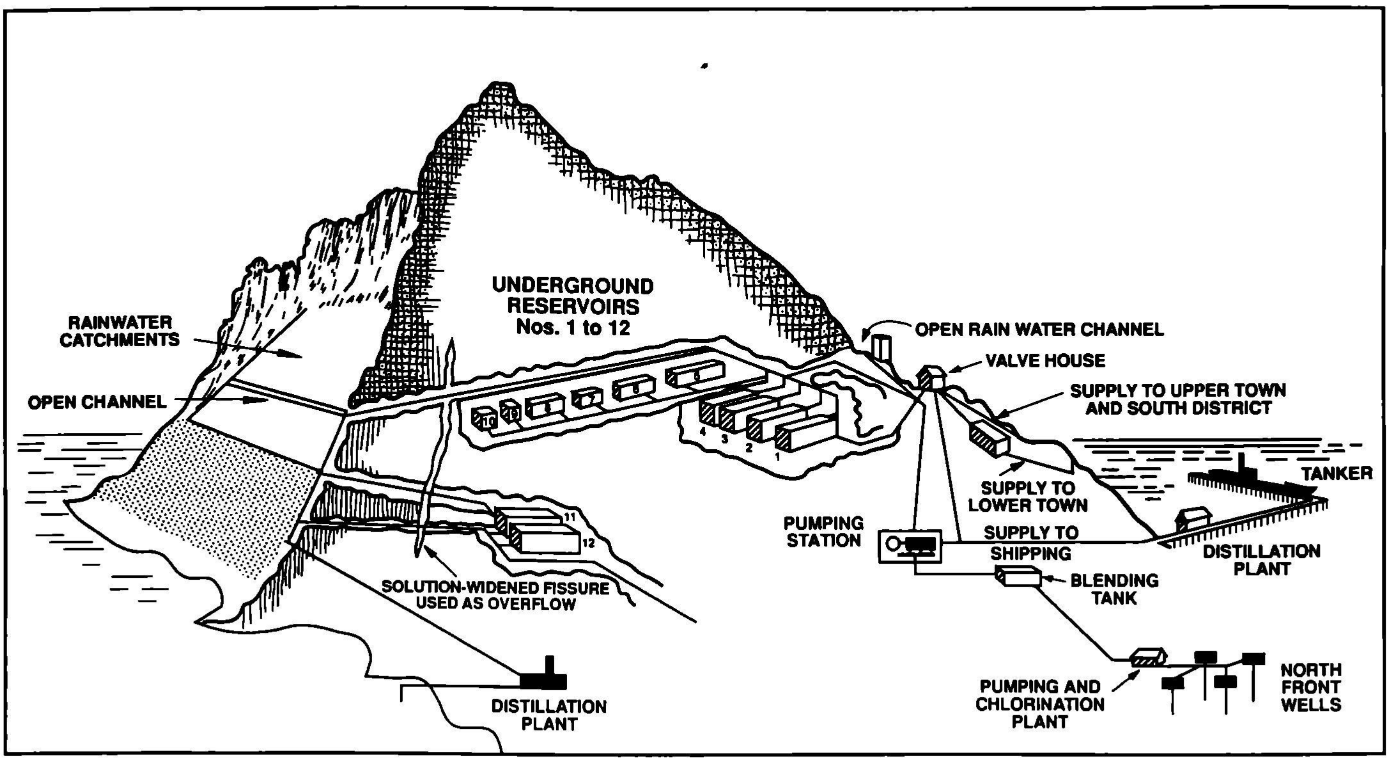


Fig.7. Diagram of collection, storage and supply of drinking water. (From Rose & Rosenbaum 1991b, based on an unpublished Gibraltar Public Works Department diagram). The former distillation plant shown to the left of the figure has now been decommissioned and scrapped, whilst the distillation plant shown to the right of the figure is being enhanced by the addition of reverse osmosis desalination plants. View from the northeast, looking south.

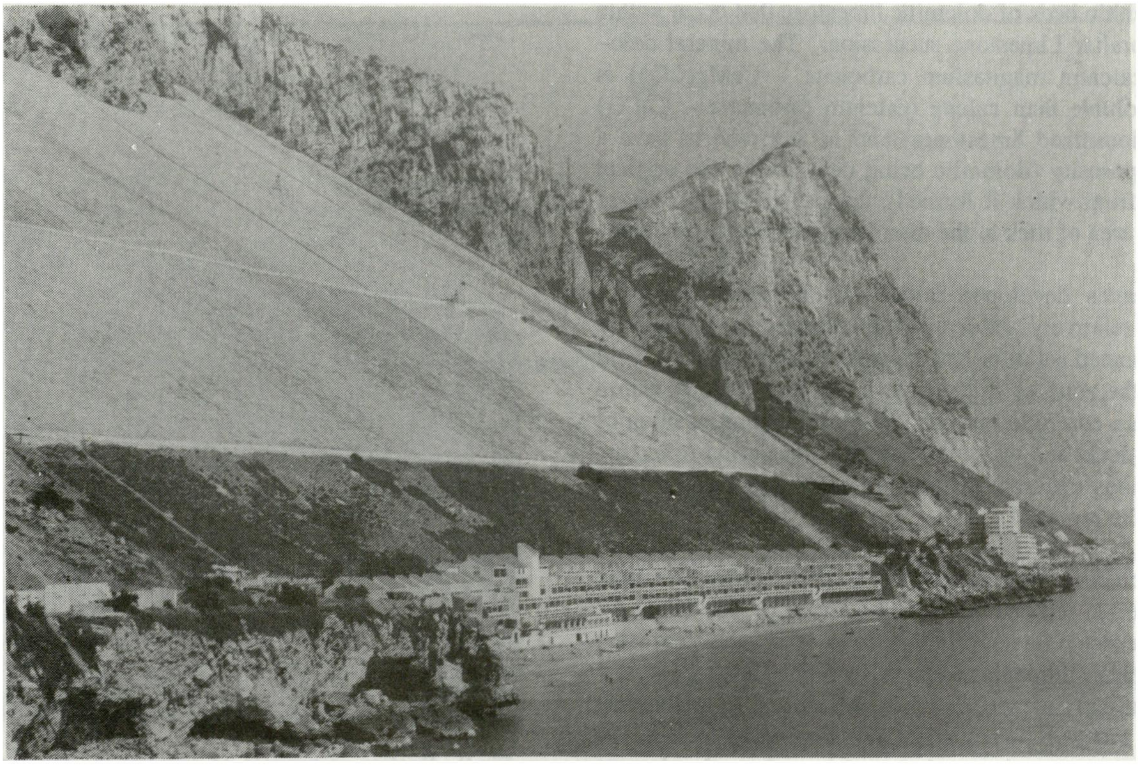


Fig.8. The water catchment on the east side of the Rock. (From Rose & Rosenbaum 1990, courtesy of the Institution of Royal Engineers). View from the southeast, looking north.

The caves originate from the dissolution of soluble rock by flowing water acidified by carbon dioxide. The carbon dioxide concentration in the water is influenced by the plant and soil cover at ground level and by the prevailing temperatures. On Gibraltar the soluble rock is in the Gibraltar Limestone Formation and here two groups of cave can be distinguished:-

a. **Sea caves.** Several levels of caves were eroded by marine action at times when sea-level differed from that at present. Some are but former terrestrial solution cavities breached by the sea but they nevertheless indicate periods when sea-level was stable for long enough for such erosion to take place. They may contain thick piles of sediment, brought in perhaps by waves or by wind action once environmental conditions changed, and indeed may have formed shelters for animals or man. Caves of this kind are well developed to the south and east of Windmill Hill Flats.

A notable example currently under archaeological investigation is Gorham's Cave on the south east coast where evidence is revealing that Neanderthal man seemingly inhabited the cave for a particularly long time, probably from about 100,000 BC to 10,000 BC (Cook, pers.comm.)

b. **Terrestrial caves.** Most formed as weakly acidic ground waters slowly reacted with the Gibraltar Limestone. Some caves developed preferentially along geological structural breaks such as faults or major joints. This was because such fractures facilitated groundwater movement thereby rapidly removing the reaction products and introducing fresh acid to the rock surfaces. Others developed preferentially within beds of dolomitic limestone that occur within the Gibraltar Limestone succession. The mineral dolomite (calcium magnesium carbonate - $CaMg(CO_3)_2$) is more soluble than calcite (calcium carbonate - $CaCO_3$) and dolomitized limestones tend in any case to have a higher porosity (dolomite being denser than the original calcite from which it formed), thereby exposing a larger surface area of rock to the dissolving acidic groundwater.

Most caves developed initially at horizons related to former relatively stable groundwater levels, because of the enhanced solution and frequent replenishment of acid within the zone of fluctuating water level. These themselves are controlled in part by the prevailing position of the sea-level and thus variations have occurred reflecting the various different sea-level stands that have existed before the present.

One such cave (St. Michael's) is a noted tourist attraction, described in reasonable detail by Shaw (1953; 1955a,b). The earliest reference to this cave is by the Augustan geographer Pomponius Mela in 45 AD. The cave is now more properly named Upper St. Michael's, to distinguish it from Lower St. Michael's Cave discovered in 1942. In that year a tunnel was being driven into the largest chamber of the Upper St. Michael's Cave so that it could be used as a store with a reasonable air circulation (Fig.10). This broke into the system now known as Lower St. Michael's Cave, which has until recently been controlled and looked after by the Royal Engineers. Shaw's (1953) account provides the best description of the system, illustrated by ten photographs, with brief bibliography. Lower St. Michael's not only contains stalagmite formations rivalling those in splendour of Upper St. Michael's, but also a lake. Some 30 metres long and up to 11 metres wide and 6 metres deep, one of its remarkable features is the size of the calcite ledges formed at the lake margin by deposition from the surface of calcium bicarbonate-saturated water. Since access to the cave system is hazardous, it is not yet open to the general public but is now in the care of the Gibraltar Tourism Agency.

In common with many other caves, those in Gibraltar usually contain one or more characteristic sediments:-

a. **Flowstone** layers, together with stalactites and stalagmites, strictly termed speleothem deposits. For these to form a cave must be wet, so that calcium carbonate can be precipitated from acidified water carrying calcium bicarbonate dripping from the cave roof, walls or floor as carbon dioxide within the water dissipates into the cave air. Many Gibraltar caves are today too dry for flowstone formation, yet contain spectacular deposits of this rock, sometimes buried beneath other sediments. These indicate periods of more humid climate in the past, such a climate encouraging growth of more vegetation than at present at the ground surface, with the release of greater quantities of humic acid, thus enhancing the acidity of the percolating water necessary for the initial dissolution of the Limestone.

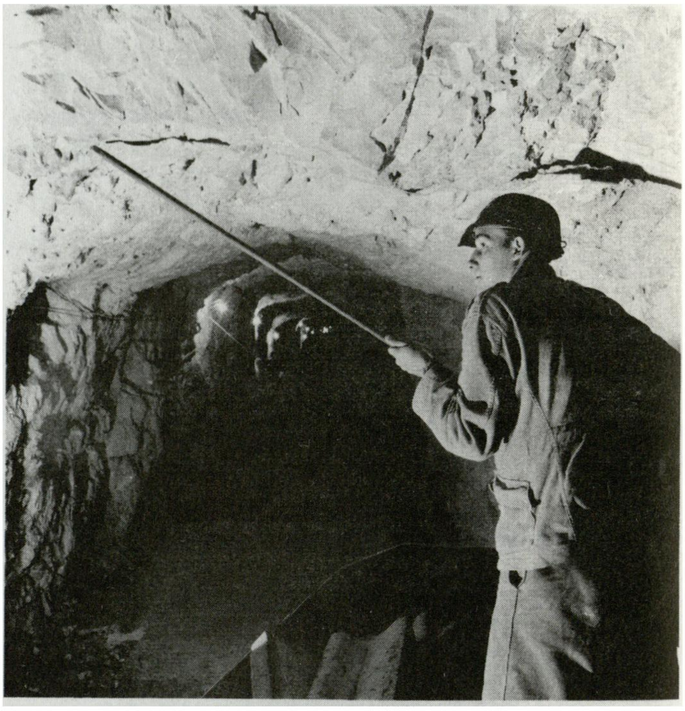


Fig.9. Scaling of tunnels, to remove the loose rock which in time develops by stress relief. (From Rosenbaum & Rose 1991b. © British Crown copyright 1991/MOD. Reproduced with the permission of the Controller of Her Britannic Majesty's Stationery Office).

b. **Cave-earth.** In some caves the surface deposit on the floor consists of a loose earth, usually soil transported into the cave by water, but sometimes with components of chemical weathering or of organic detritus. Such cave-earths tend to be fine grained, since large sediment particles tend to be filtered out through tight fractures and pore spaces, and to be well stratified; in contrast, loose, unstratified cave-earths indicate the effects of wind deposition (perhaps suggestive of a more arid climate, of greater sediment availability through low sea-level, lower vegetation cover, or variation in global dust flux). The dark red colour so characteristic of cave-earth is due to the oxidation of iron minerals within the sediment in the damp cave atmosphere.

c. **Cave breccias.** These consist almost exclusively of angular pieces of rock identical to those in which the cave is situated, with no significant wear observed on the fragments. They must, therefore, have formed from material detached from the walls or roof of the cave. None are forming at the present day, and the climatic conditions under which they formed must have been different from the other two cave deposits just described. Such breccias are thought to indicate physical weathering in the form of fresh fracturing, and develop best in a climate with frequent frosts.

Gibraltar caves have served for war time shelter (Glen Rocky) and peace time storage (Poca Roca). Some have been assessed as potential reservoirs of fresh water (Ragged Staff). A few caves (Genista, Devil's Tower, Gorham's) have been excavated by archaeologists (as described by Busk & Falconer, 1865; Warren, 1865; Brown, 1867; Busk, 1869; Garrod & others, 1928; Waechter, 1951; Zeuner, 1954, as well as Gorham's Cave currently under investigation by Dr Jill Cook and colleagues from the British Museum and the Natural History Museum in London in association with the Gibraltar Museum).

4. Visiting the Tunnels and Caves

As might be expected with military tunnels, parts of the system are inaccessible to the public. Nevertheless there are still a substantial number of tunnels and chambers which are open to visitors, together with one of the natural caves.

Sites which are regularly open during normal working hours for a fee payable on entrance are the Upper Galleries (late 18th Century cannon embrasures in the North Face), and the Upper St Michael's Cave (which is largely natural). The tunnels at Camp Bay and Keightley Way (both accessible by car and on foot) and Dudley Ward Way (accessible only by car) are in normal daily use so may be inspected by the public for free.

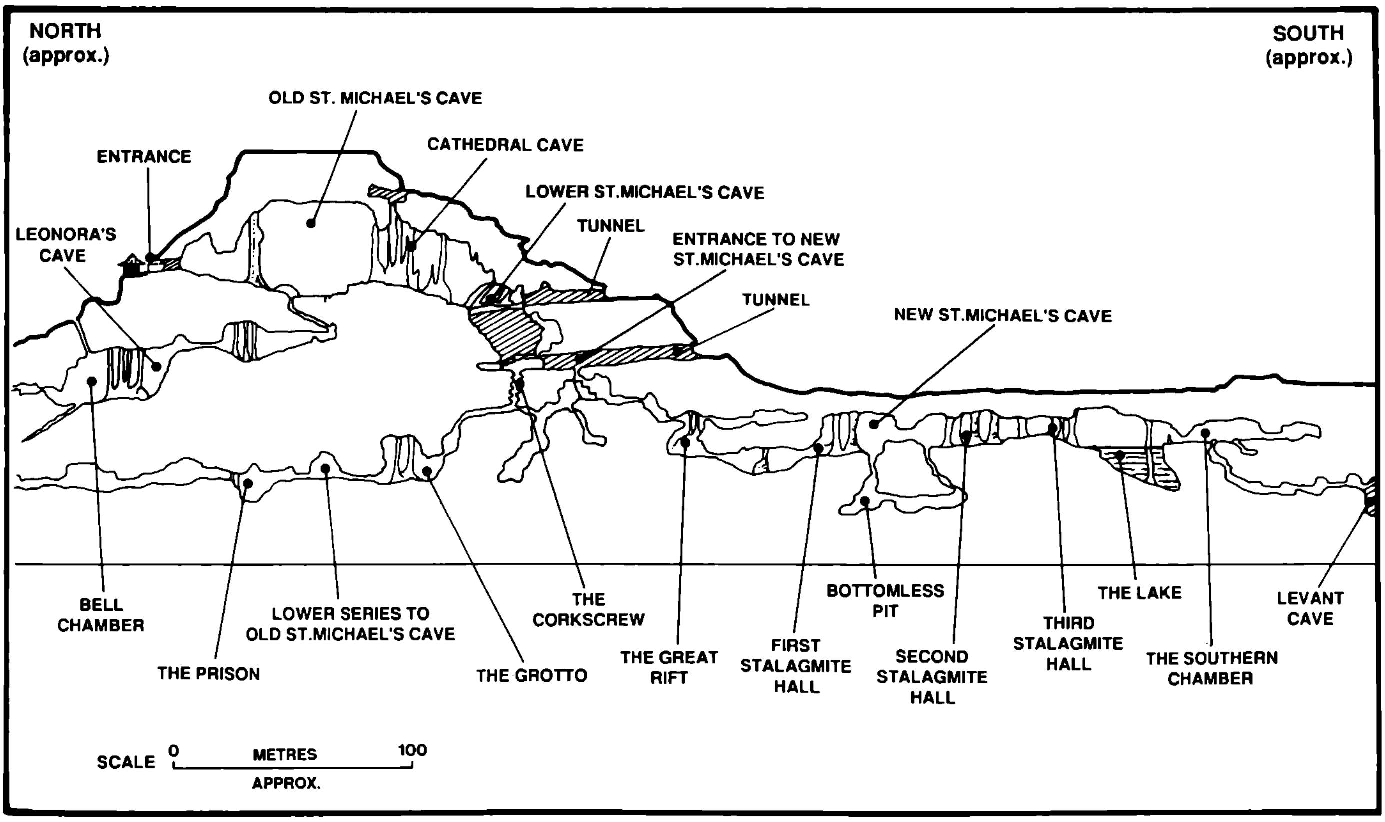


Fig.10. Cross-section through the St. Michael's Cave system. (From Rose & Rosenbaum 1990, courtesy of the Institution of Royal Engineers. Redrawn from an earlier diagram and original survey by G. Palao).

Sites which are occasionally open to members of the public, if they participate as part of an organised tour, are the Calpe Hospital and the principal military tunnels between Maida Vale and Williams Way including the Great North Road, Calpe Hole, Fordhams Accommodation, Clapham Junction and Thomson's Raise (tunnels and chambers excavated during the 1939-1945 War) (both Calpe Hospital and the principal military tunnels are accessible to parties led by guides from Fortress Headquarters in The Tower), and the water reservoirs and Upper Waterworks Tunnel (occasionally accessible to parties led by guides from the Lyonnaise des Eaux (Gibraltar) Ltd.).

Addresses for the two organisations mentioned in the previous paragraph are:-

Commander British Forces (G2)
Fortress Headquarters, The Tower
Gibraltar, BFPO 52

The Managing Director
Lyonnaise des Eaux (Gibraltar) Ltd.
Suite 10b, Leanse Place
50 Town Range, Gibraltar

Sites now under the control of the Gibraltar Tourism Agency which are not currently open to the general public but which may become accessible at some future date include the Nun's Well (the Moorish cistern near Europa Point) and the Lower St Michael's Caves (a natural cave system lying beneath the Upper St Michael's cave). Many other non-subterranean historical sites on Gibraltar are also preserved by the Gibraltar Tourism Agency on behalf of the Gibraltar Heritage Trust:-

The Director
Gibraltar Tourism Agency
Cathedral Square, Gibraltar

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A WELL AT SALTWOOD CASTLE IN KENT

R.F. Le GEAR

A well at Saltwood Castle was descended and examined by a team from the Kent Underground Research Group on 5th August 1989. The well consisted of an octagonal surround constructed over a vertical square shaft of sides 1.5m. The shaft was found to be lined with ragstone blocks and descended to a depth of 3.4m. at which point it widened slightly, the lining above being supported by carefully constructed arches of ragstone blocks on all four faces of the shaft. At a depth of 12.5m. the lining (or steining) ceased and the shaft continued in the natural Kentish ragstone, (part of the Hythe beds of the Lower Greensand).

At intervals down the shaft were pairs of 'I' section iron girders which supported the remains of wooden stages or platforms. Some of these platforms contained holes for pump rods or water pipes. The lowest platform was found at 14m. below the surface, just above the water level.

As can be seen from the plan and sections, two short adits 7.0m. long had been excavated from the shaft, the roofs of which were approximately level with the above platform. The adit walls were lined with modern style bricks, the exact date of which could not be determined.

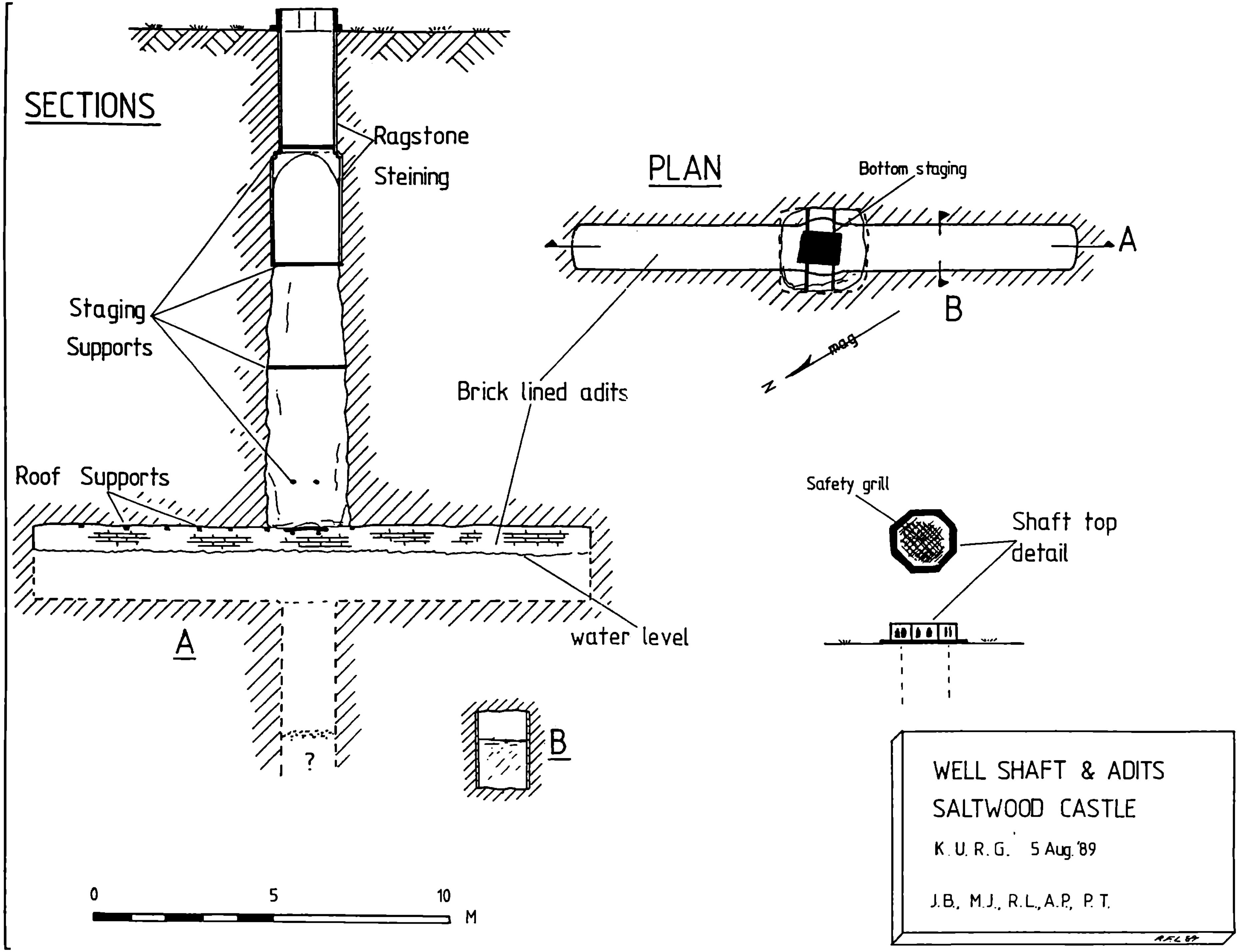
Below the bottom staging the well continued down as a circular 1.5m. diameter shaft once again lined with ragstone blocks. The depth of water was plumbed to 4.9m. giving a total depth of 19.5m. (approx 64ft). It must be noted that this depth is to the top of whatever debris has found its way into the shaft over several centuries of use. The original depth is unknown and could be many metres below.

The water in the well was found to be very clear and had a temperature of 13 Deg.C. (56 Deg.F)

It is probable that the tunnels were dug to provide an extra collecting area for the water when some form of mechanical pump was installed. The staging would have been constructed at the same time with the bottom platform housing some of the equipment. The date of these works is not known although some time around the First World War is suggested. An examination of household accounts for this period may possibly give more detail and an exact date.

Near the surface two lead pipes were noted running into the shaft. One was of crude construction and probably fed rain water from former roofs etc. into the well. The other pipe appeared to lead toward the restored gate-house and once may have connected to the pump mechanism to bring water directly into the house.

The Kent Underground Research Group is indebted to the Hon. Alan Clark, M.P. for giving permission to examine the well and underground adits. Subterranea Britannica in turn thank the K.U.R.G. for permission to reprint this article.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WELL SHAFT & ADITS
SALTWOOD CASTLE
K.U.R.G. 5 Aug.'89
J.B., M.J., R.L., A.P., P.T.
R.F.L. 89

The Team

Further comments by Michael Jackson on the well.
5.9.1989.

The above visit was the third of three attempts to organise a visit to Saltwood Castle. Alan Clark cancelled the first visit as his sons were not able to be present. The second visit was arranged some years ago and then cancelled because the BBC hired the castle to make their Tripod series of adventures. Third time lucky!

There have been stories for many years current in Saltwood village about a tunnel down the castle well - it was mentioned in a guide book, which drew my attention to it. It was rumoured to link up with Westenhanger Castle not far off, via an underground passage along which King Henry II used to travel when he occupied Saltwood Castle and wished to visit his mistress Rosamund Clifford, supposed to be living for a time at Westenhanger - there is an old tower there, known as Rosamunds Bower.

Our youngest member in the party, Paul, went down first and soon reported that there were two tunnels opposite each other 40ft down the well and the water reached his chest! He then walked along each length of the tunnel until he reached each end and proved that they led no where, being, in fact, merely a means of increasing the water capacity of the well.

I took the exploration as a good opportunity to practise my dowsing since the results could be verified soon afterwards. Using angle rods made from metal coat hangers or a metre length of water pipe, the lines of the tunnels were easily traced on the lawn and the approximate width found. I tried my pendulum for the depth of the well, asking it to gyrate once for every foot depth to the bottom; it returned to oscillation soon after sixty feet - the well being sixty four feet deep.

Front: Jim Bradshaw, Rod Le Gear
Back: Adrian Pearce, Michael Jack, Hon. Alan Clark M.P., Paul Thorne

MITHRAISM.
A “Subterranean”Religion

M.C.Black, University of London

In this paper I shall attempt to describe the legend and rituals of Mithraism, which usually took place underground, and to explain its growth and decline as a major religion of the Roman Empire.

Mithraism had its roots in India and came to the Roman Empire through Persia. A number of its ancient customs and tenets were later preserved by the Zoroastrian religion in the sacred text known as the ‘Zend-Avesta’. It was a religion which appealed particularily to soldiers (especially in the higher ranks), to Treasury officials, to traders and to merchants. This is explained when one considers that Mithras was a god of light and truth whose worshippers were expected to observe strict standards of purity and veracity and who were then inspired by the god with courage, perserverance and endurance.

The soldiers of the Roman Army brought with them the gods of their homelands which they worshipped in parallel with the ‘official gods’, such as Jupiter Best and Greatest, who dominated the parade grounds and represented the traditions of Rome, and local deities (such as Coventina and Antenociticus) in Britain.

There is evidence for the worship of the god Mithras at localities widely distributed across the British Isles including Caerleon and Caernarfon in Wales, London, Leicester, Chester, York and several sites along the line of Hadrian’s Wall, in the period 200-400 AD.

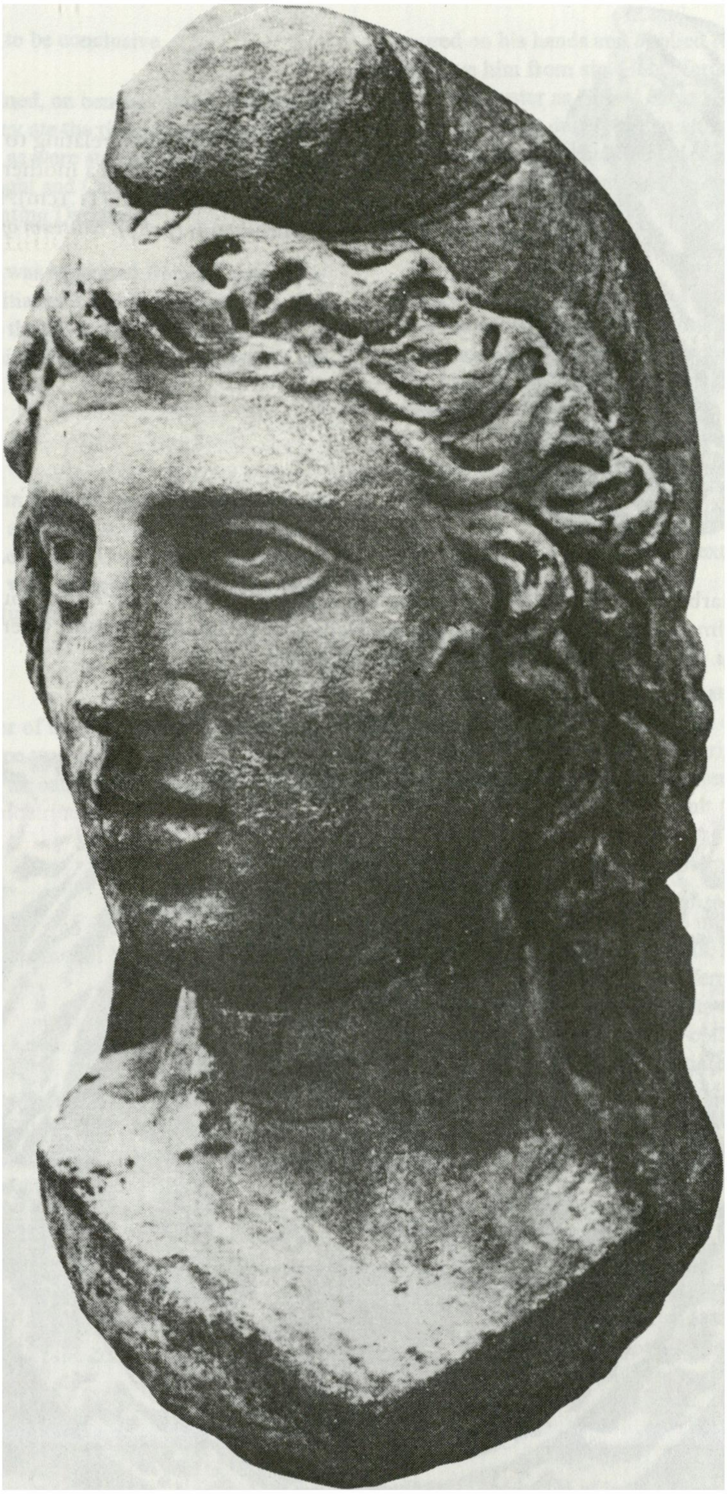
The legend of Mithras relates that he was born, observed only by shepherds, at the winter solstice, (our 25th December) directly from a rock. After various adventures, Mithras found the primaeval bull grazing in a mountain-side pasture, seized the animal by the horns, and succeeded in mounting it. Although the bull struggled and unseated his rider, Mithras did not relax his hold and was pulled along suspended from the horns. When the bull eventually tired, Mithras dragged it by the hind legs to his cave. The bull escaped from the cave and again wandered over the mountain pastures. Mithras, assisted by his faithful dog and a raven, tracked and eventually overtook it just as it sought refuge in the cave. Mithras held the animal fast by the nostrils with his left hand while he plunged his sword into its heart with his right. New forms of life sprang from the dying beast; useful plants and herbs from its body (the bull’s tail is often shown tipped with ears of corn), the vine from its blood and all useful animals from its semen.

After the death of the bull, Mithras and the Sun, waited upon by the torch bearers, the raven and other attendants, celebrated by eating its flesh. The feast over, Mithras ascended to heaven in the chariot of the Sun.

In other legends, Mithras rescued mankind from a flood (by advising the construction of an ark) and from a drought, by shooting an arrow into a rock and releasing a stream.

Mithraic Temples.

Mithraic Temples were usually situated partially or completely underground, to represent the cave in which the act of creation took place. The nave of the temple was dimly lit but lamps brightly illuminated the sanctuary where, beyond a veil, a picture, statue or a relief depicted Mithras killing the bull. It seems that the Mithraea were aligned roughly North/South but

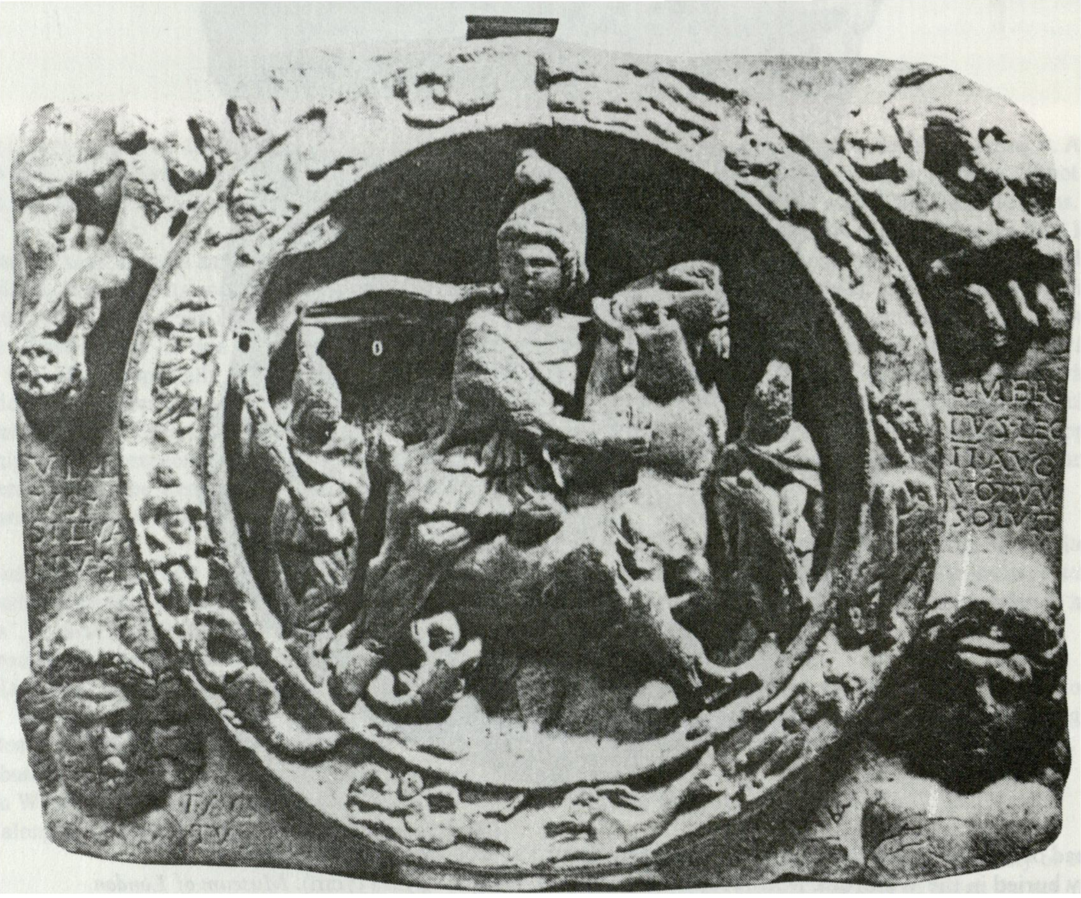


Head of Mithras in Italian marble, attributed to about 180–200; found in two pieces carefully buried in the Walbrook Mithraeum (see p211–12). Height 14½in (37cm). *Museum of London*

From; London, City of the Romans, Ralph Merrifield,
Guild Publishing, London, 1984.
Reproduced by courtesy of the London Museum

Marble votive medallion relating to a Danubian cult of twin rider-gods associated with a mother-goddess (the central figure). Diameter 4⅜in (11.1cm). Found in the Walbrook Mithraeum (p187). *Museum of London*

Marble relief of Mithras sacrificing the bull, enclosed in zodiac circle; found in Walbrook in 1889, almost certainly in the Mithraeum. Dedicated by Ulpius Silvanus, veteran of *Legio II Augusta*. Height 17½in (44.5cm). *Museum of London*



From; London, City of the Romans, Ralph Merrifield,
Guild Publishing, London, 1984.
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there is insufficient evidence to be conclusive.

The congregation sat, or reclined, on benches along both sides of the nave and it is here that they ate the ritual feasts. Small altars were set against the benches, as were statues of Cautes, with an uplifted torch representing Light and Cautopates, with torch pointing downwards, representing Darkness.

The ante-chamber or narthex was separated from the nave by a screen and it was here that initiation ordeals probably took place. There was a coffin-like pit in the floor, lined with stone and covered by stone slabs, in which a candidate was placed for some of them.

The Rituals.

The seven grades of initiates in the cult were associated with the seven planets and sometimes also with seven steps, seven altars and the seven great metals (Lead, Tin, Copper, Iron, Electrum, Silver and Gold). The grades were recorded by St. Jerome and are, in ascending order of initiation:

Raven (Corax):

The Raven was the Messenger of the Sun; he wore a raven-head mask and wings and the degree was under the protection of Mercury. The candidate took an oath which engaged him, above all things, not to divulge the doctrine and rites revealed to him.

Bridegroom (Nymphus):

The Bridegroom was the initiate who accepted the truth of the religion; he was under the protection of Venus and carried a veil and a lamp.

Soldier (Miles):

The Soldier formed part of the sacred and invincible army of his god and waged war, under his direction, on the powers of evil. Wall paintings in a Mithraeum near Naples inform us that he knelt, blindfolded and naked, and was offered a crown on a sword. He was crowned but immediately rejected it saying that Mithras was his divine crown. By this act he became Miles and could never again receive coronation; if, for example, he was awarded a crown as a military honour he would not wear it, saying "It belongs to my god". Naturally, this grade was under the protection of Mars. As part of the ceremony the candidate was branded by a red hot iron.

These three grades were known as the Servitors and even children could be admitted to them.

Lion (Leo):

The Lion was the lowest Senior or Participant. He wore a leonine head-dress and growled appropriately. As part of the initiation a candidate would undergo symbolic purifications; honey was poured on his hands and applied to his tongue in order to preserve him from sin. Henceforth (in the ritual at least) he could not touch water as he had entered the grade which symbolised fire. One of his duties was to attend to the sacred altar-flame and for this purpose he was provided with the proper implement - an altar shovel - and a supply of holy pine cones for fuel.

Persian (Perses):

Honey was also presented to a candidate for the Persian grade because of its preservative virtue; it was produced under the influence of the Moon (under whose protection was this grade) and was the food of the blessed; its absorption by the neophyte made him a peer of the gods.

Courier of the Sun (Heliodromus):

The initiate of this degree sat next to Mithras himself at the ritual banquet.

Father (Pater):

The grade of Father was placed at the peak of the hierarchy; these members presided over the ceremonies and led the congregation, for whose teaching, ordering and discipline they were responsible. These dignitaries were regarded with reverence and affection by members of the cult (as indicated by the title) and dressed in baggy Persian trousers and a Phrygian cap, which later became a symbol of other Eastern cults.

The several grades of initiates in Mithraism had different secrets entrusted to them. These secrets, however, were not communicated indiscriminately but conferred on candidates only after training or real or symbolic tests of endurance. We learn of branding, ordeals by heat and cold, fasting, scourging and journeying. In one test the initiate was blindfolded,his hands were bound with chicken-gut and he was made to jump over a water filled trench; finally, his bonds were severed with a single stroke of a liberating sword.

It has been suggested that, in one ceremony, the candidate stood naked in a pit or crypt beneath a grid on which a bull was sacrificed so that the animal's blood drained onto him, (I submit that this would have been considered a blasphemous re-enactment of the act of creation and would not have taken place.) The Taurobolium belongs more properly to the allied rites of Cybele and to the Asian cult of Magna Mater (or Great Mother).

Organisation

There was always at least one priest, sometimes several, in each temple who bore the title of sacerdos or antistes and usually, but not invariably, held the rank of Father. His prime duty was, naturally, the celebration of the services but in addition he ensured that a perpetual fire burned on the altars, prayed thrice daily to the Sun, offered up sacrifices (probably chickens or geese as their dismembered bones have been found in the Carrawborough Mithraeum) and generally acted as an intermediary between men and the gods.

The management of the Mithraic community was invested in a council of decurions headed by a 'president' or master who was elected annually by a general assembly. In addition there was a 'curator' (who managed the finances) and a 'lawman' (who would defend their cause in the courts). Most important, persons of consequence, 'patrons' would provide efficient protection and financial support. Tertullian tells us that a Father of Fathers (Pater Patrum) would have general jurisdiction over all the initiates in the city; this Grand Master was permitted to marry once only and held office for life.

The Doctrine

A Mithraist believed in the conscious survival of the divine essence that dwelt within him and in punishment and rewards beyond the grave. After death, his soul, if stained by an impure life, would be dragged down to the infernal depths, to be subjected to a thousand tortures or to be reborn as an unclean animal. If, on the other hand, his merits outweighed his faults, he would ascend into paradise.

The heavens were divided into seven spheres connected by a ladder with eight successive gates. The soul of the initiate, who had been taught the correct pass words, was able to climb this ladder, abandoning, en route, every vice and passion, until he entered the eighth heaven to be greeted by Mithras himself.

The Rise and Decline of Mithraism.

The cult of Mithras spread quickly from the East; by the end of the third century AD it was popular in the Rhineland and Britain. However, it never came near to being universally accepted as it suffered from two great weaknesses: it was exclusively male and it did not demand unconditional and exclusive allegiance.

Mithraism attracted the especial hatred of Christians because they interpreted Mithraic rites as a blasphemous or diabolical imitation of their own practices. Although there was much similarity, Christians could not accept that rites that had a particular significance to them had an equally sincere but completely different significance for Mithraists.

The many analogies between Mithraism and Christianity included:

1. Birth of God on 25th December.
2. Birth observed by shepherds.
3. Adepts formed 'sodalicia' and called each other "Brother".
4. Purification by baptism.
5. Abstinence and self-control were regarded as meritorious.
6. A Heaven, populated by the beatified, was situated in in the upper regions and a Hell, inhabited by demons, in the lower
7. A Flood occurred at the beginning of history.
8. The Immortality of the soul.
9. A judgement after death and final resurrection of the dead.

Mithras was singled out for attack by Christians when they obtained power and the wholesale destruction of Mithraea across the length and breadth of the Empire demonstrated their success. The Emperor Julian, usually called The Apostate, considered himself to be under the special patronage of Mithras and tried to reintroduce paganism. When he died on a military expedition against the Persians the fortunes of Mithras continued to decline. Mithraea were destroyed, often contaminated by the entombment of their priests, holy writings burnt and the doctrine condemned.

Conclusion.

My interest in Mithras was kindled when I stood in the porchway of the Mithraeum at Brocolitia (Carrawburgh, Northumberland) over twenty years ago. Since then, I have returned many times to the thin strip of England from the Tyne to the Solway which was such a stronghold of the religion for a couple of centuries. My curiousity prompted me to investigate the practices and beliefs of those times from the rather thin information available to us and the more I discovered, the more I became fascinated by this 'subterranean' religion.

Acknowledgements.

I would like to express my gratitude to the staff of the Department of Archaeology of the University of Newcastle, whose library and museum provided much useful information; to Mrs Agnes Stickings, former Head of Classics at Langley Park School for Boys (Beckenham, Kent) for supplying reference material; and to Mr Lloyd Bookless and Mr David Hunt of Hailebury College (Hertford) for helpful discussion following the preparation of the first draft of the paper.

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THE ENIGMA OF CROCKET'S HOLES, NEWENT, GLOUCESTERSHIRE

David E. Bick

Legends of secret passages or tunnels connecting old mansions, churches, or other prominent buildings are common, and the evidence for such underground ways is sometimes too great to dismiss such tales out of hand. A particularily intriguing example of such a legend was for long known in the parish of Newent, though it is now largely forgotten. It related to an unusual, perhaps unique, claimed under-ground way in that this reputedly connected subterranean chambers or caverns, rather than structures above ground. Souterrains or underground chambers of great antiquity, some being Iron Age, are well known in parts of Ireland and Scotland and in Cornwall, with passages communicating with the surface, but are decidedly rare in the rest of England.(1)

Of the two terminal caverns (for which there is sound evidence), one was under almost level ground just to the SW of Great Cugley Farm (SO 719233), where two footpaths cross. The farm is at an altitude of about 65 metres, some 3 km S of Newent. The spot has been determined from a study of Bryant's county map of 1824, and of the 1st edition of the Ordnance Survey's 25" to the mile plan. The second is assumed to have been at approximately SO 698209, at an altitude of about 250 metres, on the E side of May Hill and not far from its summit. This spot is nearly 3 km from the first. The intervening ground is, geologically, very varied, and significantly faulted. On the evidence in the current 1:50,000 geological survey map the excavation at Cugley is in New Red Bromsgrove Sandstone; any direct tunnel thence to May Hill would evidently traverse the Raglan Formation, the Downton Sandstone (members of the Old Red Sandstone), Wenlock Limestone, Wenlock Shale, further Wenlock Limestone, Ludlow Shale, Downton Sandstone, Raglan Formation and, finally, May Hill Sandstone - an interesting sequence! In the 185 metres rise that the tunnel would have to make, it would pass under gently rising ground for the first 1.5 km, and steeply rising ground thereafter. The average gradient of the tunnel would have to be of the order of 1 in 16.

MAY HILL CAVERN

The May Hill cavern is well-known from Rudder's account of 1779, when it was called Crocket's Hole

> 'because one Crocket and his companion Horne used to hide themselves there in the persecuting reign of Queen Mary' (2)

However, Rudder obtained this information from a manuscript history of Newent written in 1707 (3) where we read

> '...Yarleton Woods ...very large, extending almost to the top of [May] Hill. Some paces above ye wood is a place called Crockett's Hole many yards deep where it is affirmed that one Crockett and Horne did conceal themselves in Queen Mary's reign.'

Horne was later burnt at the stake in Newent, but this unhappy story does not concern us.

THE CUGLEY CAVERN

It has given rise to much confusion that the cavern at Cugley was also similarly named, but the circumstance is not surprising in view of the linking tradition. The first record of the Cugley Cavern, which may be termed Crocket's Hole North, was due to Stephen Ballard, engineer to the Hereford & Gloucester Canal (4), who visited the site in 1834. He supposed it to be an entrance to an iron-mine at Black House (5), some 400 metres towards May Hill, but in this he was almost certainly mistaken. (Black House Farm is at approx. SO 715224.) Ballard's notes in his diary (6) are as follows:

> "Saw Croke's Hole at Cugley, a subterranean passage cut in the sand rock. It is not known when this passage was cut or for what purpose. It extends under the earth a great way. Old Mr Collar of the Wood Gate says he remembers that some miners who were employed at the coal works at Boulsdon (7) went into this passage a great distance but not to the end, the damp having prevented their progress. They had torches made of pitch rope. I crept into it about 6 or 7 yards [2m] but the passage was much reduced in size by falling sand from the roof. There is plenty of room just within the entrance, a sort of appartment 10 or 12 feet [3m] wide out of which a small passage leads which is so much reduced in size that a person could scarcely creep along it, but Mr J. Matthews (8) says his brother some

> years ago went in a considerable distance and found a spacious appartment the roof of which had a great quantity of bats hanging to it ... There is no mound at the mouth of this cavern and it appears strange, what could be done with all the sand and stone that must have been carried out. I have no doubt it is an artificial passage for the tool marks are now plainly to be seen in some parts."

Ballards description was very largely confirmed about 50 years later in an important paper by G.H.Piper, President of the Woolhope Naturalists' Field Club (9). It also dealt with the tunnel legend and mentioned May Hill Cavern or Crocket's Hole South. The relevant parts are as follows:

> "On Cugley Farm some 300 yards [91m] west of the Highway from Newent to Huntley, may be seen a large excavation in the New Red Sandstone, locally known as Crockett's Hole. It is in the corner of a field near to the farm-house and until 1884 was a spacious cavern cut out of the solid rock, which is here very soft and easily worked. It could be approached only by a hole in the bank of the hedgerow in the adjoining field, which is on a much lower level. Unfortunately, in that year the weight of some horses broke in the roof and for ever ruined an object of great local wonderment and interest, sanctified by traditions of incidents which occurred more than three centuries ago; a long period, but one that would probably represent a fraction only of the antiquity of the excavation."
>
> "The principal cavern would appear to have been some 14 feet by 12 [4 x 3.50m], and 9 or 10 feet [3m] high. I satisfied myself about the height by pushing a pole down into the soft sand that had fallen from the roof.
>
> Near the summit of May Hill, on the eastern side not far from the keeper's lodge, is another large hole in the earth. The distance thence to Cugley is about one and a half miles [3 km] as the crow flies, and an ineradicable belief exists that a subterranean passage leads from one point to the other; and persons now living relate how their own immediate friends and relatives have endeavoured to prove the truth of the tradition and clear up the mystery.
>
> The belief in this myth is supported by the circumstance that a large opening at the base of the cavern at Cugley may yet be seen. It is many feet below the surface of the field and at the part of the cave nearest May Hill: it inclines in that direction but its length or continuance is quite problematical.
>
> About 1665 one Fairfax, a disbanded soldier, advised by Lilly the astrologer, came down from London and opened this hole in hopes of discovering great riches therein, which drew many people thither. Some went into the hole and told incredible things concerning it...
>
> In 1884 I interviewed Mary Mayo, a widow then living in Newent, aged 71. She told me the cave was reached by descending a flight of 15 steps and that she had been there frequently with other children, but although she never went far into the inner passage her two grand-fathers Paul Apperley and Richard Cowell had been more adventurous.
>
> They knew there was a chest of treasure about midway between Cugley and May Hill because after toiling for several hours, much of it on their hands and knees, they saw what appeared to be a large box, but it was on the other side of a stream of water so deep and wide they could not cross, and while they were deliberating the ... candles ... fell in the water and they were left in utter darkness. The difficulties in crawling out and the terrors occasioned, prevented all further attempts at exploration ... The date of it would appear to be early in the reign of George III. Many other similar tales are current round May Hill..."

Whether or not we incline to believe in the treasure and the efforts to find it, from the descriptions of Ballard and Piper, the existence and antiquity of an underground room and tunnel at Cugley or Crocket's Hole North is established beyond question. It was still a distinct feature within living memory and according to local information, still accessible. It is now marked only by a shallow depression at the side of the field at grid reference SO 719232. The spot is close to two public footpaths which intersect nearby, as shown on the 1:25,000 Ordnance Survey map. The tunnel position could be located by several methods and to gain access would be an object of no little historical and scientific interest. It is to be hoped that, with the aid of a sympathetic landlord, this might one day be achieved.

Much less is known about Crocket's Hole South, on May Hill. Attempts have failed to trace the keeper's lodge mentioned by Piper, but from fieldwork and the first edition Ordnance Survey six inch map a likely site is in a field on the edge of the wood some 500 metres SE of May Hill summit. By a kind of negative assarting [clearing land for agriculture] the field was converted into a conifer plantation which is now quite densely accompanied in places by bramble and bracken, making inspection difficult. Certainly the ground here would have proved an uncongenial host, being hard Silurian sandstone.

These two caverns and associated tunnel well deserve a closer study, and it is sobering to recall that without the tragedy of Horne to entice past antiquarians, much less of their history would be known today.

References and Notes

1 Crawford, H (Editor) (1979) Subterranean Britain, John Baker, London. pp. 100 - 144.

2 Rudder, S (1779) A new history of Gloucestershire, Cirencester. pp. 563 -564.

3 Gloucester Record Office D/1810/13.

4 For a biography of Ballard, see David Bick (1979) The Hereford & Gloucester Canal, pp. 63 -73.

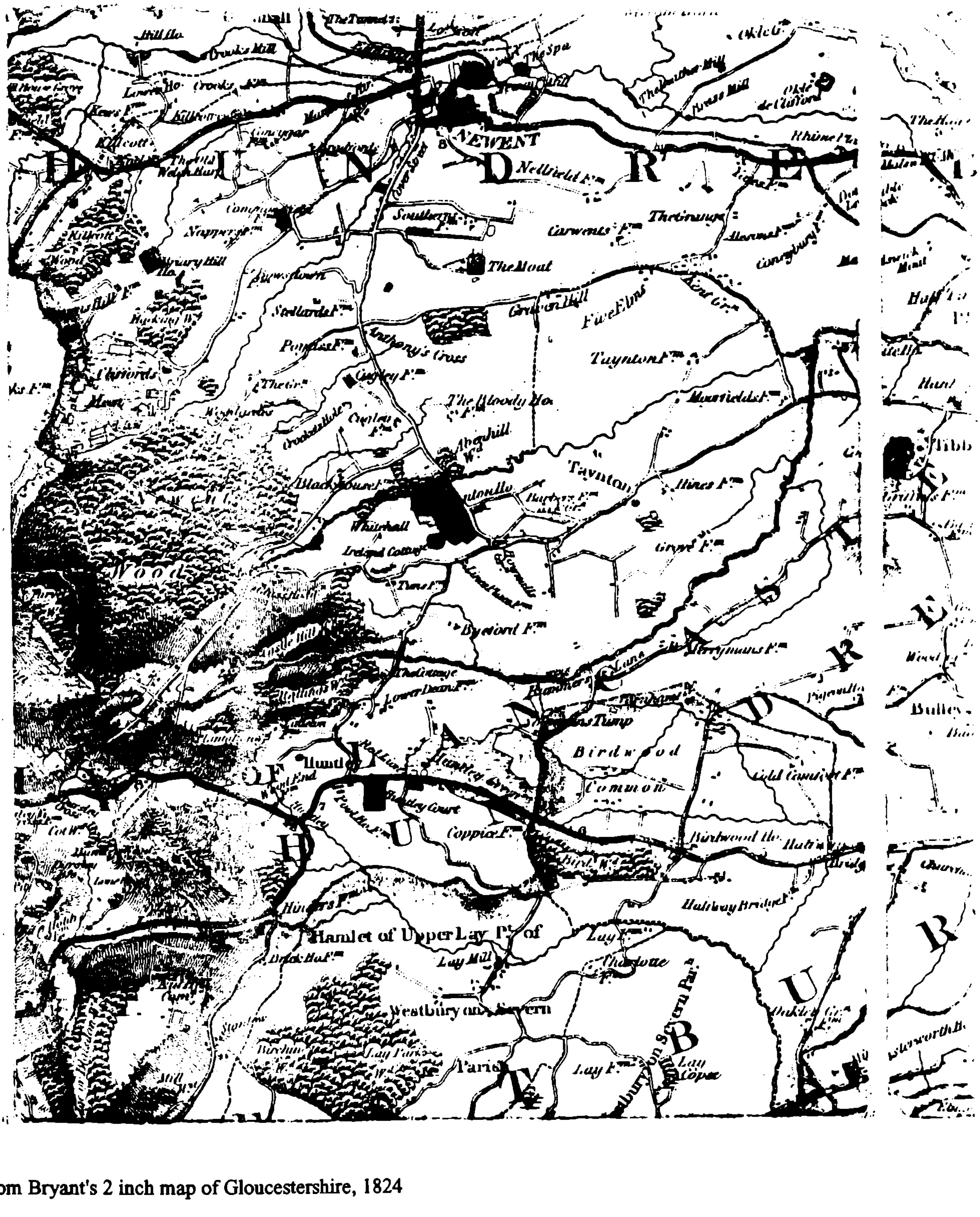
5 For details of local mining, see David Bick (1987) The Mines of Newent and Ross.

6 The Ballard diaries are deposited in Hereford Record Office.

7 Wood Gate is 0.5 miles west of Cugley; Boulsden is one mile to the north-west.

8 This may have been John Matthews, who had a small estate at Boulsden.

9 Piper, G.H. (1886) On Crockett's Hole and Horne, the Newent martyr, Transactions of the Woolhope Naturalists Field Club. pp. 89 -92.



From Bryant's 2 inch map of Gloucestershire, 1824

Crocket's Hole can be seen near Cugley, south of Newent. May Hill is just off the map to the south west of Newent Wood.

DIGGING BATH STONE; AN INTERIM REPORT

David Pollard.

INTRODUCTION

Almost 20 years of research into this fascinating industry has prompted the writer to produce this brief report. Ongoing research and field work continues to yield new information, also new methods of digging Bath Stone are still evolving, hence this report can only be an interim one.

Other aspects of digging Bath Stone such as cranes, tramways, organisation of labour and transport are only mentioned in passing, however taken all together late 19th century Bath Stone quarrying methods were significant in making Bath Stone competitive over a huge area, and were copied elsewhere.

Bath methods were adopted wholly or in part at Dundry (Somerset/Avon), Weldon (Northants), Beer (Devon), Upper Balls Green, Nailsworth (Glos), Seacombe and Winspit (Dorset). On the 16 March this year underground quarrying restarted at Beer in Devon by a Wiltshire quarry gang using current Bath Stone methods, thus history repeats itself.

GEOLOGY

Bath Stone is a sedimentary oolitic limestone belonging to the Great Oolite division of the Jurassic period found to the south, east and north east of the City of Bath. It outcrops high up on the hillsides in the valleys of the Avon, Midford Brook and By Brook.

The Bath Stone strata or beds dip gently to the south east, thus the stone is found at greater depths under the flatter uplands to the east. It is mainly due to this geological feature that new types of quarry evolved in the 19th century to get at the stone.

Bath Stone is fairly uniform in structure without any plane of cleavage and relatively soft when in the ground thus enabling it to be worked freely in any direction, hence its older name of Freestone. Other geological features such as the thickness of the beds and the occurrence of natural vertical breaks known as joints in the beds determine the method of quarrying.

HISTORICAL OUTLINE

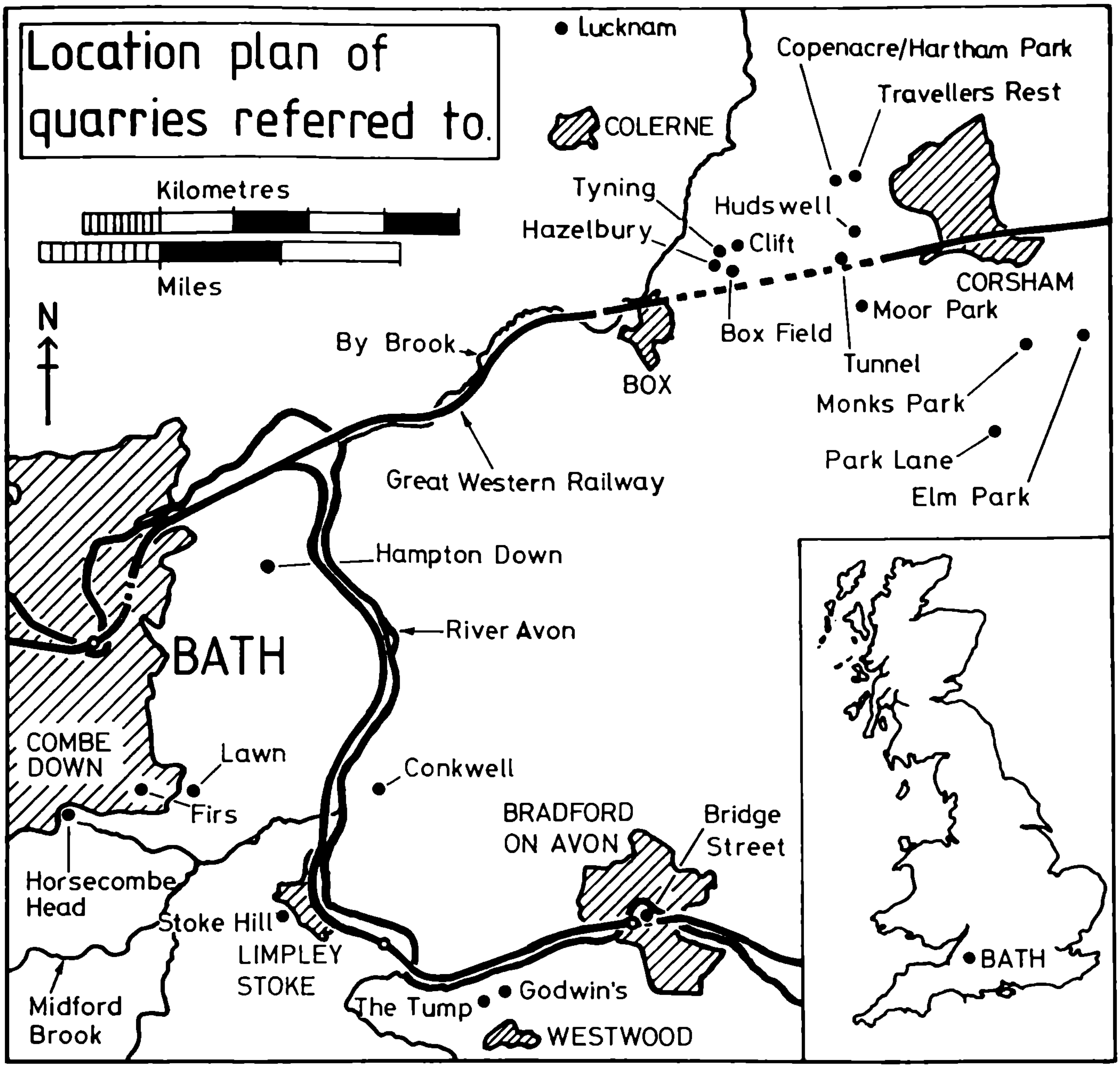
The archaeological record shows that Bath Stone was used and therefore quarried during the Roman occupation of Britain, the Saxons also built with the stone and probably quarried it in some instances, evidence of Norman and early English work is plentiful up to 30 miles from the nearest quarry.

The documentary record dates from 1189 with a grant of a quarry at Hazelbery in Box, archive evidence for the Box quarries survives from all the following centuries up to closure in 1968. Early documentation of other quarries is rather patchy, but from the beginning of the 19th century onwards most quarries are fairly well documented.

Improved transport links helped the industry to expand, particularly the opening of the River Avon Navigation in 1727, the Kennet and Avon Canal in 1810 and then the Great Western Railway in 1841.

In the 18th Century the main expansion was south of Bath and was aided by technical innovations such as quarry railways and cranes. From 1795 further expansion took place along the line of the K & A Canal to Bradford on Avon, then from 1844 most expansion took place east of Bath mainly at Corsham and Box.

Today there are three working underground quarries, Monks Park at Corsham, Westwood Quarry and Stoke Hill Quarry in Freshford parish. Lawn Quarry on Combe Down is now the only working surface quarry.



QUARRY TYPES

Bath Stone quarries can be conveniently grouped into eight basic types:-

1) Hillside or Outcrop quarries
2) Hole quarries
3) Undermining quarries
4) Level headings.
5) Inclined roadway quarries
6) Vertical winding shaft quarries
7) Underground ridded down quarries
8) Slope Shaft Quarries.

1) Hillside or Outcrop Quarries.
These were the earliest quarries and are found where the beds of stone outcrop on the hillsides. The more successful ones developed into very large quarries. It is worth noting that after the advent of underground quarrying the Box quarrymen called this type of quarry an 'open quarry'.

2) Hole Quarries.
These were an 18th century development away from the hillsides and are found where the depth of the ridding or overburden above the freestone is shallow, such as on Combe Down. Access to the quarry floor was normally by an inclined roadway or ramp. As with the hillside quarry all the beds of stone were quarried.

3) Undermining Quarries
These developed from both hillside and hole quarries because of the need to preserve the surface of the surrounding land or to avoid quarrying the less valuable overburden, thus making it necessary to undermine the head or bounds of the quarry. The transition to underground quarrying began by the early 18th century and was widespread by the mid 19th century. These quarries often have several entrances, rope or chain grooves on some of them show that initially the block stone was dragged out into the open by surface cranes or windlasses.

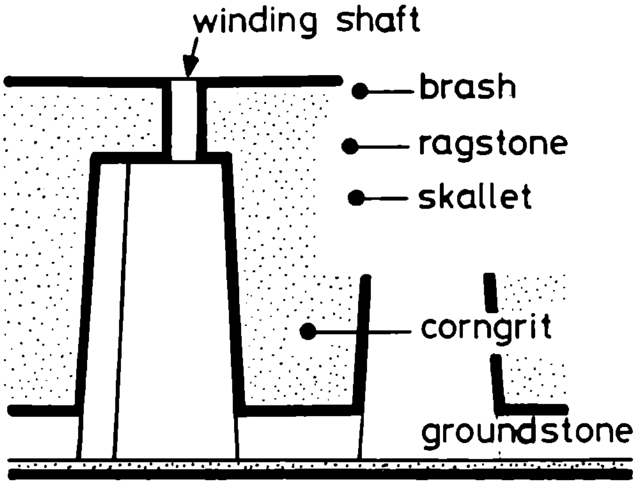
4) Level Headings.
These underground quarries are situated on the outcrop and the surface has only been quarried back to provide a good entrance.

5) Inclined Roadway Quarries.
The increased demand for the stone during the 19th century lead to the opening of new types of quarries on the flatter uplands in west Wiltshire. In the first of these types an inclined roadway was cut through the overlying rocks until the beds of Bath Stone were reached, then underground quarrying would start at that point.

6) Vertical Winding Shaft Quarries.
Although some of the circular 'light hole' shafts at Firs Quarry on Ccmbe Down may have been used for winding stone to the surface during the 18th century these were essentially an addition to an existing undermining type quarry. The first true vertical winding shaft type quarry was sunk at Traveller's Rest at Corsham in ca. 1810 Ten quarries of this type were developed until 1914, vertical winding shafts were also added to other types of quarry.

Winding shafts were usually rectangular, measuring about 14 ft. x 7 ft. known exceptions are Hudswell Quarry which had twin circular shafts, Winding shafts and some 19th additions to Firs Quarry. Winding was accomplished by horse cranes known as 'Ginny Rings', and latterly stationary steam engines and scotch derrick steam cranes; hand cranes were used in a few instances where the depth was not great.

7) Underground Ridded Down Quarries.
This interesting type combines a short vertical winding shaft with working methods akin to the well developed outcrop quarries at Box.
The outstanding example is Box Field Quarry, part of which is known as the Cathedral because of its vast proportions. Worked from 1829 to ca. 1850 by Job Pictor it differs from undermining in that the primary direction of quarrying was downward through all the beds of stone over a large area rather than forward through the beds of Ground Stone only.



Underground ridded down quarry at Box Field.

/

8) Slope Shaft Quarries.
This was one of several innovations introduced by Messrs. Randell & Saunders in ca. 1845 at Tunnel Quarry at Corsham, the slope shaft is an inclined tunnel driven at an angle of around 30 degrees to the horizontal to meet the beds of Bath Stone and was specifically designed to accommodate a narrow gauge tramway with steps alongside for the quarrymen. The driving of the slope shaft was often preceded by the sinking of a small diameter trial shaft to prove the quality of the stone, this would later serve as an air shaft for the quarry.

Twenty four slope shaft quarries were started up to 1904 but some failed to develop, the last slope shaft was driven into Copenacre Quarry in 1908 to replace the existing vertical winding shaft. Shaft haulage was by stationary steam engines, portable steam engines driving cable drums, ginny rings, twin cylinder single drum capstans, a gas engine, a Fowler ploughing engine and finally electric winches.

Due to large scale quarrying over a long period of time, some quarries have progressed from one type to another and where once separate quarries have joined up underground it is possible as at Box to find several quarry types within the compass of the whole quarry.

A few quarries possess features not mentioned above, in particular Brewers Yard which has been worked on two levels. The Corngrit and Skallet beds were quarried on the upper and more extensive level, and Ground Stone on the lower level.

SELECT GAZETTEER

Although examples of nearly all the above types of quarry can be seen, most are privately owned and some of the underground ones are potentially dangerous.

The gazetteer lists quarries with surface features visible from public roads and footpaths without trespassing. BY LAW PERMISSION MUST BE SOUGHT TO VISIT ANY PART OF A WORKING QUARRY. An asterisk denotes a working quarry.

1) HILLSIDE OUTCROP QUARRIES
Box; Hazelbury (ST 8365 6935) Great and Little Tyning (ST 8362 6950)
Westwood (ST 8070 5977); Conkwell (ST 7907 6230)
Hampton Down (ST 7765 6530)

2) OPEN QUARRIES
Combe Down; Rock Lane (ST 7587 6240); Lawn Quarry * (ST 7660 6245)

3) UNDERMINING QUARRIES
Combe Down; Rock Lane (ST 7587 6240)

4) LEVEL HEADINGS
Box; The Clift (ST 8380 6972); Kingsdown Quarry (ST 8092 6702)

5) INCLINED ROADWAY QUARRIES
Freshford; Stoke hill Quarry * (ST 7792 6072)

6) VERTICAL WINDING SHAFT QUARRIES

7) UNDERGROUND RIDDED DOWN QUARRIES

8) SLOPE SHAFT QUARRIES

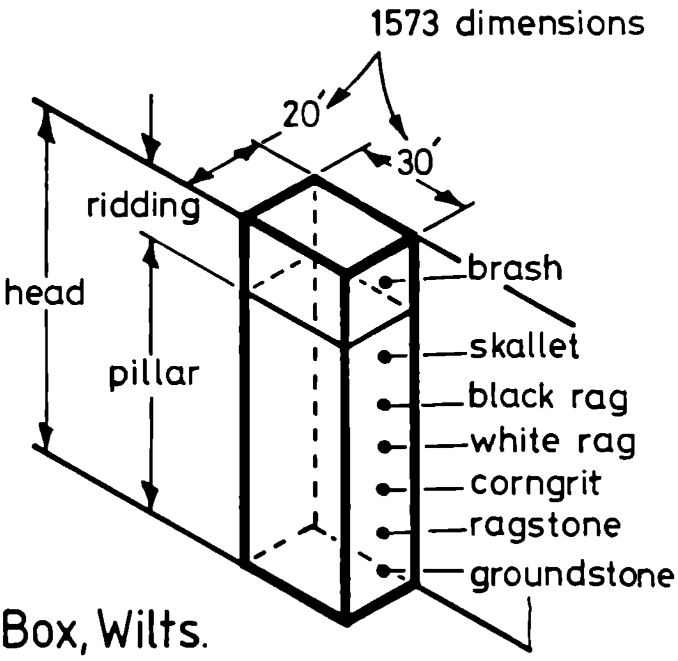
Examples of these last three quarry types can be seen at the Underground Quarry Centre at Corsham which incorporates parts of Traveller's Rest and Pickwick Quarries.

WORKING METHODS - HILLSIDE OUTCROP & HOLE QUARRIES

At this stage the reader should bear in mind that in the Bath Stone area the natural vertical joints or Master Joints tend to run roughly parallel with each other in a north west to south east direction. In some quarries there are also other joints that run at 90 degrees to the master joints. The width of joints varies greatly, but one or two inches is common.

Quarrymen use joints to save cutting, thus the direction of quarrying is usually across the joints and along the joints, thus producing rectangular blocks with little wastage. No horizontal cutting was necessary.

The earliest known references to the method of getting the stone refer to Box and date from the 1570s. In December 1571 John Grome of Rydley was paid 'for his ploughe at Hazilberie quarre rydding the same' and later 'To him also and John Hendye, for rydding of the roble in Castle Dyke quarre 30 fote one way and 20 another'.



Box, Wilts.
Hillside quarry
ridded down from the top c.1782

The method was described in rather more detail in 1849 by Joseph Head who wrote 'the course of working the quarries in the neighbourhood generally was to rid them down from the top and the mode adopted in ridding was to clear away from the surface about four or five yards deep before you got to any stone that was saleable, that stone that was come at first is called skallet the next corngrit and then a small bed of rag after which you reach the groundstone the most valuable in the Quarry. After the top is cleared away then the stone all the way down is called a Pillar and is measured according to the clearing each way'. John Chandler another Quarryman also mentioned the White rag and Black rag beds which came between the Skallet and the Corngrit.

Quarry leases often specified the manner in which a quarry was to be worked
and reveal some quarry terminology of the time.

An Indenture dated 10th May 1789 required the lessee 'to keep the head of the quarry eighty four feet wide or as near as the two joints would admit or as much under as convenient for the good of the said Quarr...', clearly natural joints were exploited where ever possible and in the above instance determined the size of the quarry.

Information about the tools used at this time and in earlier years is lacking but it may be safely assumed that the holing pick and holing iron were used for cutting wedge holes, wedges driven between chips with the aid of sledge hammers could split or raise blocks from the parent bed. Picks were probably used for cutting Upright Jads or channels around the blocks of stone in the absence of natural joints. Large iron bars for shaking stones loose must have been essential and scappling axes were certainly used to roughly dress stone.

It is likely that simple portable lifting devices such as shearlegs were used to lift block stone. Presumably ropes were used for lifting in earlier years and chains later. When the Lewis was introduced for fixing rope or chain to blocks is not known. Lewis holes were started with a holing pick and finished off with holing irons.

Remarkably these simple tools with the addition of a few others were also used for underground quarrying and continued in use until recent times. Cranes were used at Combe Down from about 1730 and were common by 1812.

UNDERGROUND QUARRYING

The principle of quarrying across the joints and along the joints and the use of joints to avoid cutting also applies to underground quarrying.

It is essential that one surface of a block of stone is free before it can be detached, therefore when digging stone underground it is necessary to cut at least one horizontal slot known as the 'jad' or the 'picking' into the rock.

The ceiling and ground above is supported by pillars or walls of unhewn stone, the width worked between them is known as a breach and the quarried space leading to the breach is a heading.

Where the first breach was made is not known, but the Horsecombe Head area of Combe Down sometime in the late 16th to mid 17th century is probable. Leland referred to 'quarre' in this area in 1542, stone from'Horscomb Hed' was supplied to Longleat House in 1568, later in 1749 John Wood wrote 'it now bears the Name of Horse Combe Quarry from its Situation in the Comb..; and it is not only the most westward, but the oldest of all the Penetrations that have been made into the bowels of the hill in search of Free Stone'.

In 1663 The Danish scholar Oluf Borch visited Bath and later wrote 'a cave opens up on a nearby hill, hollowed out by those who live in the place for stone for buildings'. This is the earliest evidence of an underground Bath Stone quarry.

A well developed part of nearby Firs Quarry on Combe Down can be dated to the earliest years of the 18th century, but as in many early quarries situated in jointed or broken ground close to a hillside, evidence of cutting is scanty. A little distance away wedge holes can be found in the remaining halves of joints. The size of blocks was quite small, some were worked up in the quarry as there is a partly sawn block lying by the oldest breach.

The next reference is dated 1722 and refers to three quarries bounded on the north by Haselbury Quarries at Box. It says 'whether they have liberty ... to quarry any further underground is uncertain'.

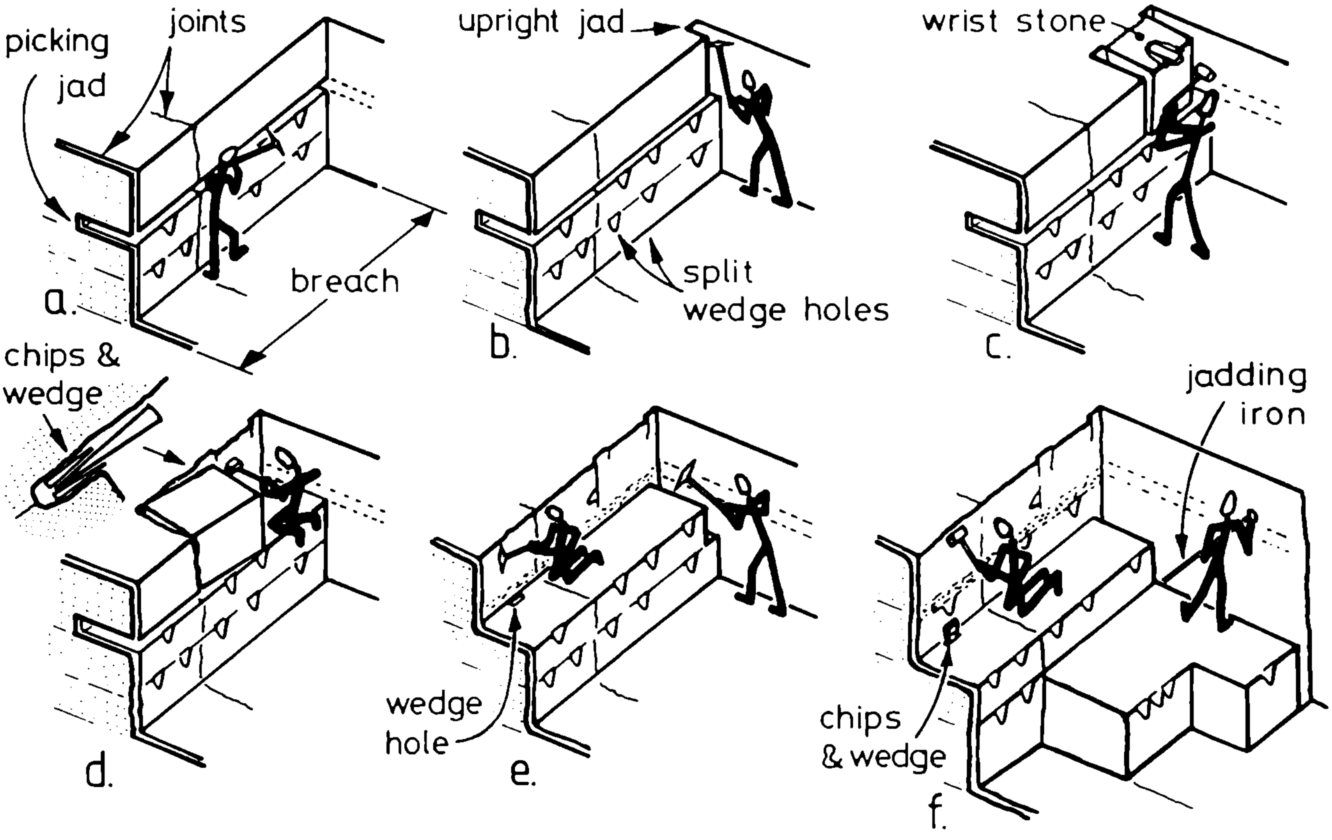
At Box, undermining the Head of the quarry or what we would now call the Face appears to have been discouraged or limited during the 18th century.
For example, in 1726 the Lessees of Mr Longs Quarry '..Shall and will ... Digg down, undermine and manure the said Quarry ... according to the usual way of quarrying, Keeping a Good Head and not undermine the same except it be to follow a Joynt in the Rock..', and in 1789 at Sir Lathan Sumsions Quarry '... the said Quarry should be undermined on the South side to the Road ... and in the north side or Little Tyning Eighty Four feet from the side joint and never to be undermined more than Forty feet at the East, North and South sides before the head of the Quarry'.

As late as 1849 undermining was known to Box quarrymen as 'picking' or as 'picking holes', thus identifying the principal tool involved.

At Box Field Quarry from 1829 to the 1850s the pick was used to cut the jad below the top or first bed of stone to be got and often between two joints, so that the top bed would be supported only at the back.

However if there was only one joint then an 'upright jad' would be cut from ceiling level through the top bed down to floor level, or when quarrying at 90 degrees to the joints two upright Jads would be cut.

The first stone or 'wrist' was got out by driving a wedge or 'driving iron' into the bedding between it and the ceiling bed above, thus forcing the wrist downwards into the jad and breaking it off at the back. Removal of the top bed gave room to get the beds of stone below the jad.



Underground quarrying with pick, chips & wedges and jadding iron.

The method used was to pick out a line of wedge holes between two joints or upright jads and parallel to the longest free side of the stone to be got, then wedges would be driven in between 'chips' to split the stone off.
To get a stone block out of the rock by splitting, it must be free on three vertical sides and one surface.

The cutting of deep upright jads was a slow business, a man could do about 12 superficial feet of jadding per day, wasting a width of only 4 inches of stone. The jad was started with a pick and continued with a 'jadding iron' until several feet deep. Jadding irons were up to about 7 feet long and 1 inch in diameter with a steel chisel edge about 1/4 inch wide.
The marks of both tools can be clearly seen on quarry walls, and show alternate areas of left and right handed jadding.

The supreme example of jadding is Box Field Quarry where short vertical shafts were sunk through the brash and the upper ragstone beds into the beds to be quarried, then a large area of stone was cleared and ridded downwards for depths up to 80 feet or so in much the same way as a surface quarry.

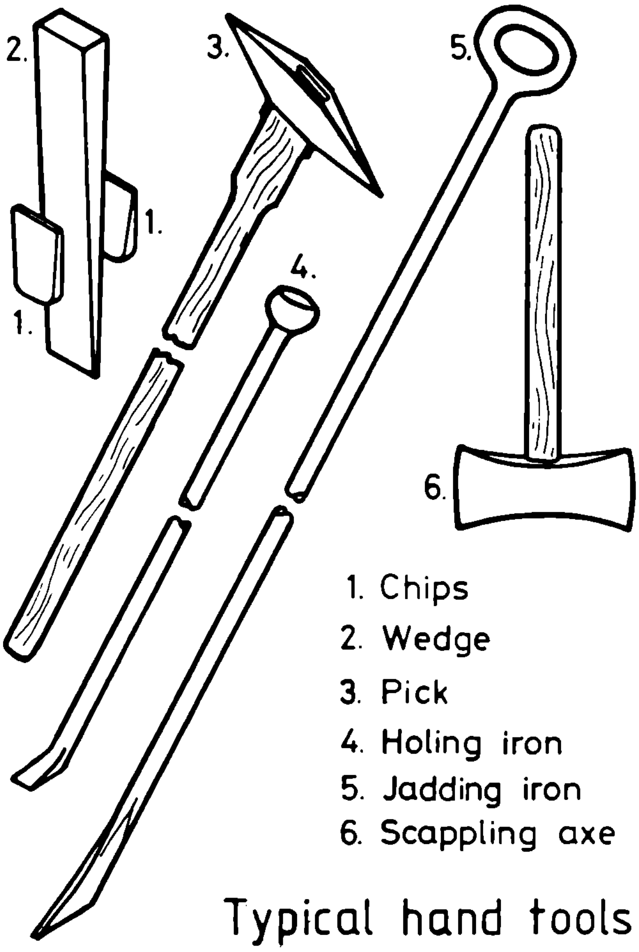
Quarrymen were paid by volume but only for saleable block stone, thus the stone had to be sound, free from all defects and rectantangular in shape with flat surfaces, Blocks were dressed by chopping off the unwanted stone or 'much' with a scappling axe.

During the 1840s the 'frig bob' saw came into wide spread use for making vertical cuts, thus giving bigger and better blocks with less much to be scappled. Hitherto stone saws were similar to a carpenters bow saw and unsuited to underground quarrying. The change over appears to have been gradual as there is evidence of jadding and sawing being used at the same time. Rough masonry blocks split with chips and wedges were supplied from Bradford quarries for bridge piers on the Devizes branch railway as late as 1857.

The frig bob ranged from 5 to 8 ft long and from 10" to 12" in depth, it appears that deeper jads were picked to accomodate its length, and to accomodate its depth the top bed or wrist was still driven down into the jad. This practice continued in some places as late as 1867.

A feature of early sawing is that shallow upright jads were cut from ceiling level down to the horizontal jad to free the sides of the top bed.
These were made with a jadding iron used in a near horizontal position leaving very distinctive marks on walls and ceilings.

Regular sharpening of a frig bob with a triangular file eventually converted it into the shallower 'razzer' saw, this lead to the jad being picked at ceiling height in the top of the uppermost bed of stone to be got, this extended the ceiling forward and cleared the top surface of the stone for a horizontal distance of up to about 5 feet.



Typical hand tools

The picks used for picking in 1840 had wide blades like a holing pick, typically about 7/8 inch, but over the next 30 years or so there was a progressive reduction in width until jad picks became pointed at both ends.

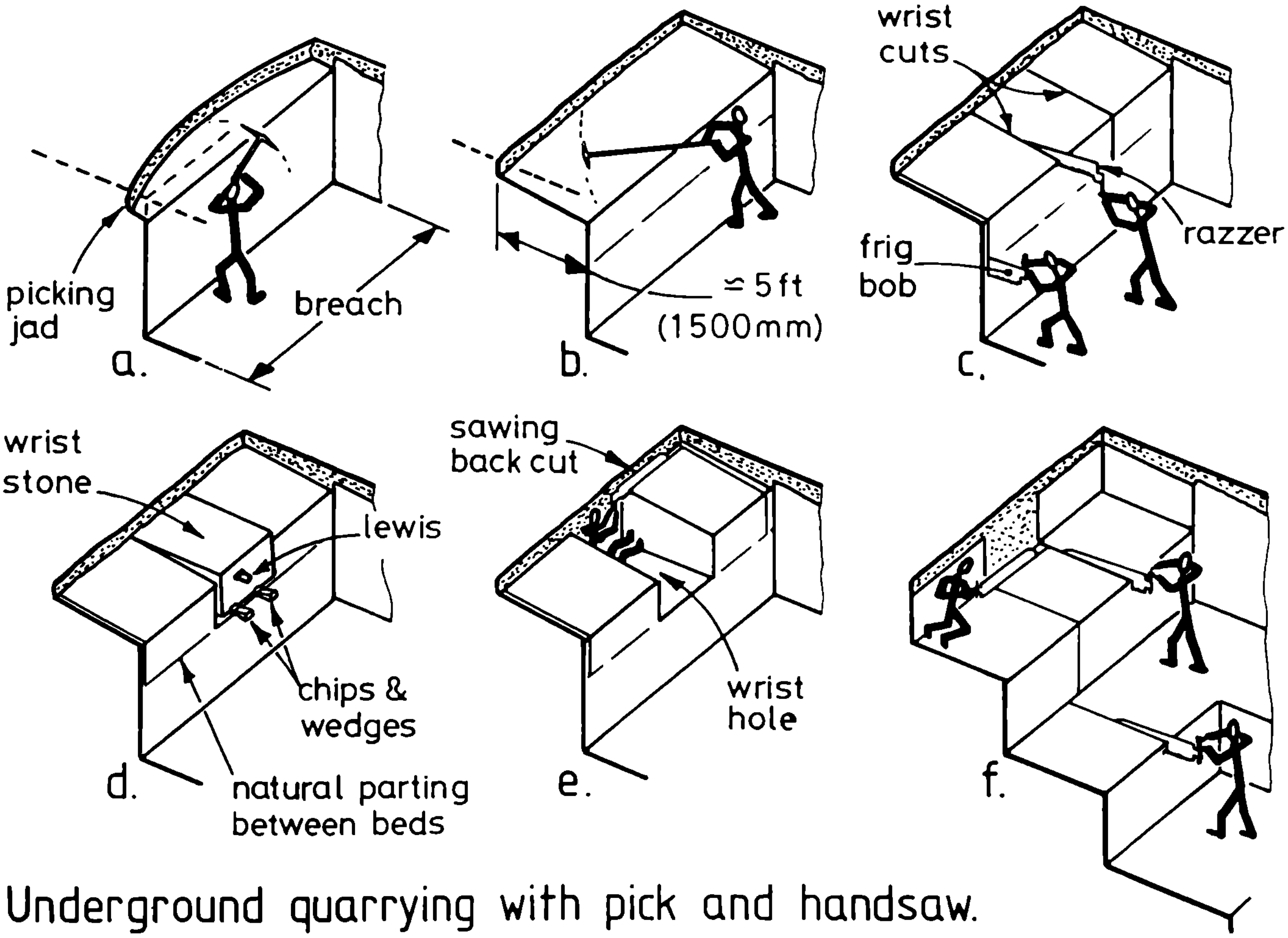
By 1871 Pickers were using a set of three or four picks to pick out the jad. They were made with helves ranging from 3 to 5 and even 6 feet in length, so that the reach of the pick extended to the back of the jad as it advanced. The head was fixed to the helve at an oblique angle, known as spreading and weighed from around 7 lbs diminishing to 3½ lbs as the length of the helve increased. In 1871 at Box where the stone is harder a picker did an average of 13 superficial feet of picking per day and would deliver about 26 blows per minute with the longest pick.

Gangers or quarrymen bought their own tools, usually from the firm but also local ironmongers and probably blacksmiths.

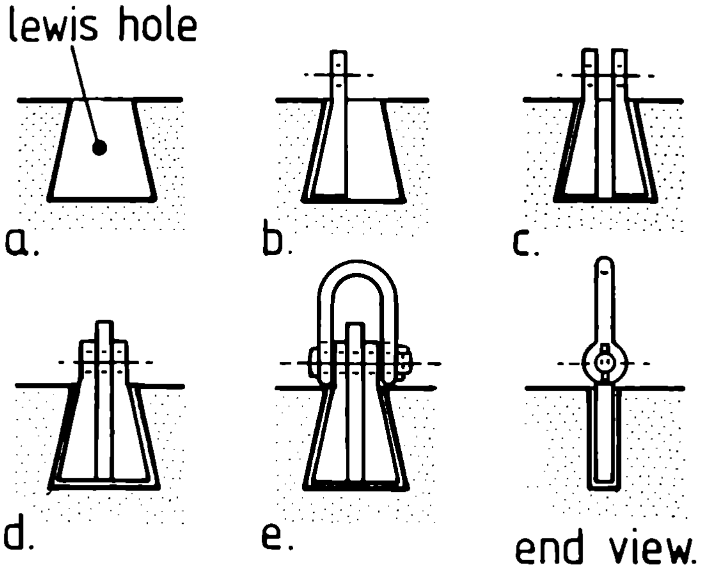
Picks and scappling axes were sharpened in the quarry on a slab of Pennant sandstone, re steeling was done by the quarry smith at the quarrymans expense.

Jadding irons were used for reaching into the furthermost corners of the jad and for knocking off projecting stone at the sides of the jad. It was difficult to cut jads deeper than about 5 or 6 feet with picks, but a depth of 7 feet or more could be accomplished with the jadding iron, which was directed by hand so as to deal out a succession of blows against the face of the jad. For deep horizontal cutting the jadding iron was greased to slide freely over a pick helve, which was laid across under it to give support. The last hand picking was done by Bill Inchly at Park Lane Quarry in 1958.

Following the picking of the jad under the ceiling, the wrist stone was got out by sawing with a razzer two cuts at right angles to the breach about 2 to 3 feet apart and slightly converging towards each other at the back of the jad. By driving in wedges between chips on the bedding or parting with the bed underneath the wrist stone, would be forced upwards into the jad and would break from the parent bed at the back. The wrist stone was pulled out with a hand crane by means of a chain attached to a lewis fitted into the front of the stone. The wrist hole vacated by the wrist stone gave access to saw along the back of the remaining top bed stones and, following their removal to the top of the beds below.



Underground quarrying with pick and handsaw.

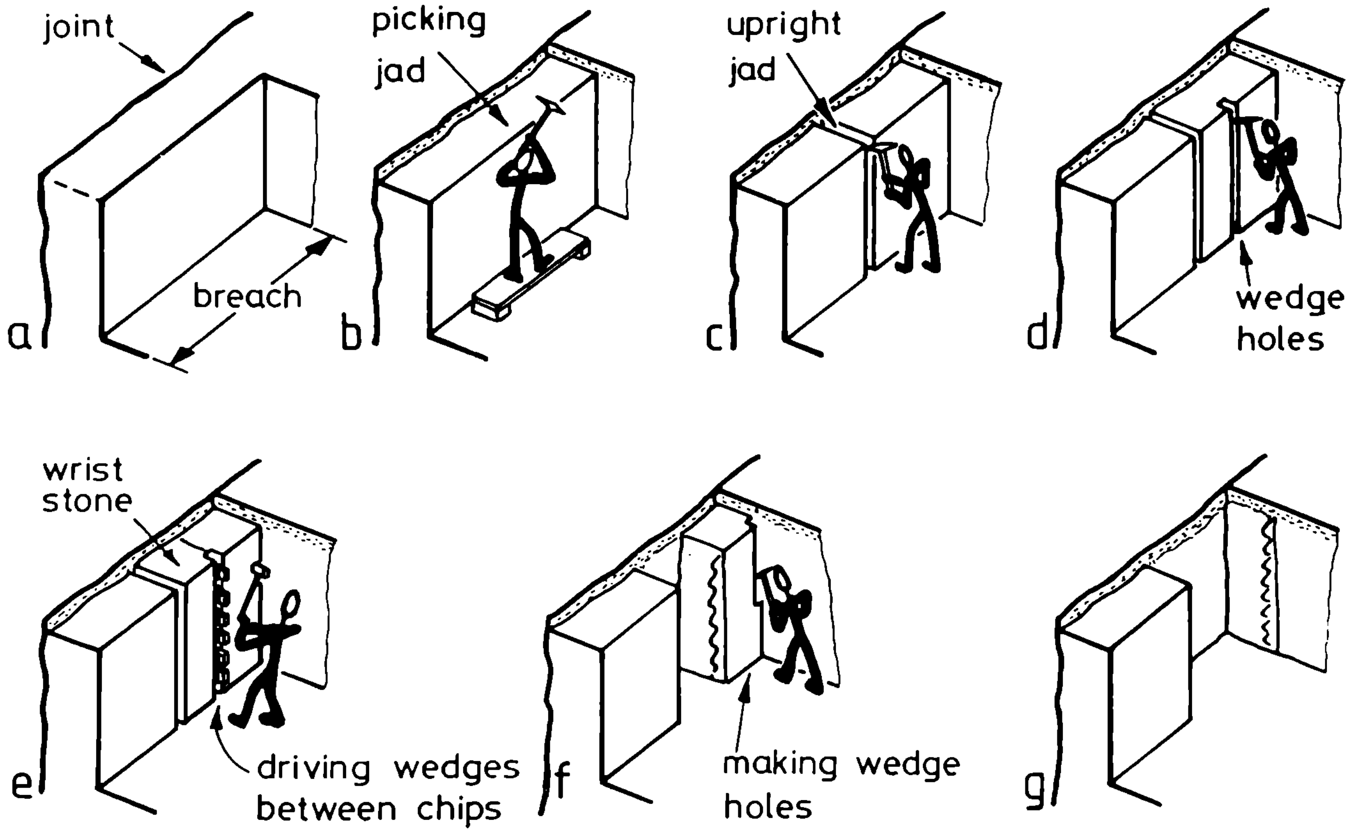


Lewis assembly

Blocks of stone that were sawn or free on four sides but otherwise still in situ were shaken loose from the bed underneath by inserting a heavy iron lever under one side and shaking it up and down. The lever was known as a big bar, jumper bar or handy bar.

In 1871 it was claimed that 15 square feet of the softest stone could be sawn in an hour, however the writer believes that 5 square feet per hour is more realistic. During the 1880s saws were supplied by Spafford & Co of Sheffield and G & T Gray, triangular sharpening files were made in later years by Tyzacks. The hand sawing era ended in 1968 when the Clift Quarry at Box closed.

At the Westwood and Stoke quarries only one bed of stone was normally dug, this bed is 7 to 8 ft deep and called for quite different methods to those described above.



Westwood. Godwin's Quarry. early 19th century quarrying

Underground quarrying started at Godwin's Westwood quarry shortly before 1804, the practice here was to pick out a very narrow jad over the stone for a depth of around 2 to 3 feet and across a breach of 10 to 12 feet.
When quarrying across the joints it was necessary to pick an upright jad from the front of the breach to the joint at the back. Then by picking out a vertical line of wedge holes, the wrist stone would be wedged and split off sideways towards the upright jad, then the other blocks were wedged off towards the wrist hole. When quarrying along the joints it was necessary after the removal of the wrist stone to cut an upright jad along the back of the blocks to be got. No evidence of jadding irons has yet been found at Westwood, they were probably unnecessary.

The first evidence of a frig bob type saw at Westwood is a sawn wall conveniently dated July 1840. Here and at Stoke the thin saw cuts gave less room to wedge the wrist stone sideways and it may be from this time that the practice of underpicking the wrist stone started.

Stones quarried at Godwin's Quarry in April 1849 were around 40 cubic feet in size and thus weighed about 2½ tons, a crab winch was used for pulling and loading stone. Cranes were introduced here later than elsewhere.
The newer Tump Quarry used cranes and saws from the beginning and was sending out blocks in excess of 80 cubic feet by 1878.

Hand methods prevailed until 1940, but after the war the old order gave way to complete or part mechanisation in four quarries. At Park Lane one gang of 5 men still dug stone by hand, in 1949 they dug 17,158 cubic feet.
The end came in 1958.

MECHANISED QUARRYING

The first challenge to hand methods came in 1851 from a steam powered rope driven sawing machine fitted with eight 24 feet long reciprocating saw blades. This did the work of 70 men in Randell and Saunders Corsham Down Quarry. A working model of it was demonstrated at the Great Exhibition, after which no more is heard of the model or prototype.

In 1878 Randell and Griffin patented Machinery for 'Getting, Sawing, and Working Stone', this was two separate machines, but similar in that they were both attached to adjustable vertical columns fixed between the quarry floor and ceiling. One machine drove two or more rotary cutters for cutting jads and the other a reciprocating saw, the machinery was to be driven by 'steam or compresse air, or be adapted to animal or other motive power', apart from the specification nothing is known.

James Saunders Randell remained innovative to the end of his very long life. In May 1898 at his instigation The Bath Stone Firms Ltd approached Siemens & Co. of London offering them a reward of £1000 if they could enable the Bath Stone Firms Ltd to reduce the cost of stone by 1d per cubic foot, apparently this came to nothing.

In November of the same year a Mr. W.Boss invited the Stone Firms Manager to see his newly invented compressed air picking machine. In June 1900 it was agreed to accept an offer from Anderson & Son of Glasgow to supply an electrically powered picking machine with three heads. At the Firms AGM in 1901 and 1902 it was announced that experiments by a Scottish firm for cutting stone were continuing, again success was elusive.

During July 1903 the Firms directors resolved to make arrangements to try the Champion Machine as a picker at Sumsions Monks Park Quarry using compressed air. On the 20th November they resolved to buy a picking machine from Champion Chanelling Machines Ltd for £100, a second hand Ingersoll Sargeant & Co. air compressor from the makers for £92, a steel air receiver for £18 10s and pipes for £5. The compressor was mounted on a concrete plinth behind the engine house and powered by a rope drive from the engine flywheel. In January 1904 they resolved to buy 2500 feet of piping to convey the compressed air to the picking machine of Mr. Membrey.

The Bristol Master Builders Association saw it at work on 21st September 1904 and reported that 'this drill is a great time saver, is working admirably and its operation was watched with great interest'.
This machine was reputedly successful, but is believed to have been the victim of sabotage, presumably it reduced the pickers earnings.

In 1925 the Firms Directors discussed the rival Elm Park and Corsham Down Bath Stone Cos recently installed pneumatic picker, it was thought to be quicker but more expensive than hand picking. The picker and its compressor were at Westwells Quarry in February 1929, but were excluded from the sale of the quarry. This machine was used extensively at Elm Park Quarry, the picking marks show it had a very small cutting head.

In December 1937 the Bath & Portland Stone Firms Managing Director considered mechanising the Bath quarries, however the conversion of quarries into ammunition depots by the Royal Engineers demonstrated which machines were suitable. 'Samson' Arc Shearers made by Mavor & Coulson Ltd of Glasgow and Siskol picking machines made by Champion Chanelling Machines Ltd were both used on conversion work, but were originally designed for coal mining.

After the war the Firms decided to completely mechanise production at Moor Park Quarry. Early in 1948 they took delivery of Model 34 FST Samsons Nos 6065, 6066 and 6067. These robust versatile machines can cut both horizontally and vertically, and are in essence a 440V 3 phase electrically powered caterpillar tracked chainsaw. The cutting arm is known as a jib. Other innovations were an electric winch for the slope shaft, a Ruston and Hornsby diesel locomotive and three prototype electric pillar cranes which were designed by the Firms and built by their Plant Hire Department at Box Wharf. In 1949 the 6 men working here produced 42,796 cu ft. of stone.

In 1952 Monks Park Quarry was mechanised with the equipment used at Moor Park plus three new electric pillar cranes. An inventory of the equipment used here around 1960 will be found in Appendix 1.

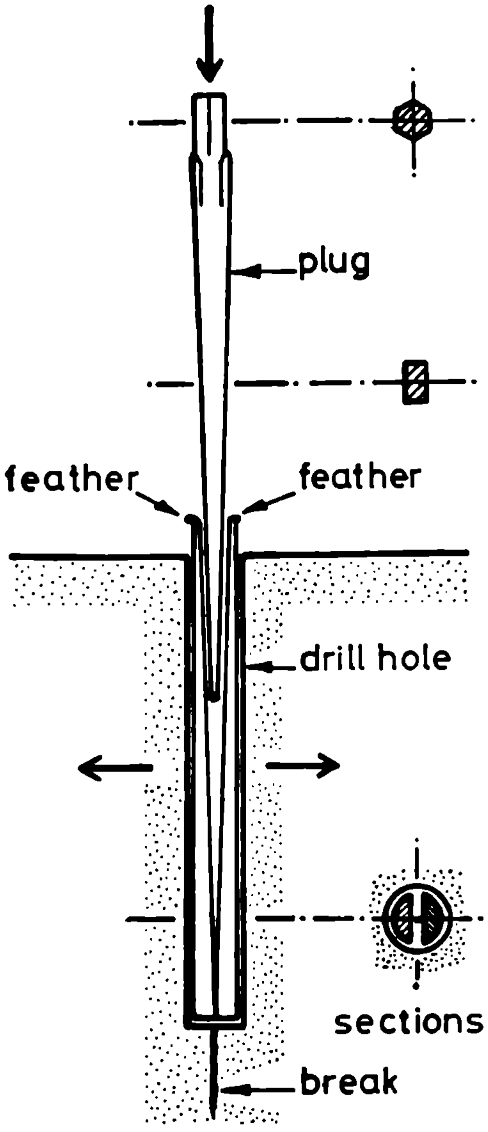
At Monks Park the picking is made below the top bed, followed by the vertical cuts thus enabling the top bed stones to be driven downwards as in early hand digging. The back cuts are made by small hand held electric Vamo chain saws, block stone is prised from its bed with the aid of a Pavement Breaker air pick known as 'the bumper' by driving in wedge shaped drill bits one above the other until the stone lifts.

Plugs and feathers are also used for splitting off blocks, they were introduced in 1955 and work on the same principle as chips and wedges but are more efficient.

Meanwhile in September 1951 the Firms ordered an electric Siskol picking machine, the 'Siskol', originally named the Champion was a column mounted percussive drilling machine which could deliver about 350 blows per minute and made a segmental form of cut under the ceiling. This machine and another one dating from 1946 were used at Hartham Park until closure in 1958.

Hand sawing continued at Hartham until 1958, by which date a novel working method had evolved, the upper two beds were sawn solely by hand and removed by crane. This then gave enough height between the ceiling and the beds below in which to use a drill. These beds were dug on the principle of one clear surface and three clear vertical sides. Two parallel lines of holes about 3 feet apart would be drilled from the front to the back of the stone, these would be then be sawn through with a frig bob. These holes speeded up sawing. Another line of holes was drilled along the back of the stone between the two saw cuts, plugs and feathers inserted into these and then the stone would be split off along this line of holes.

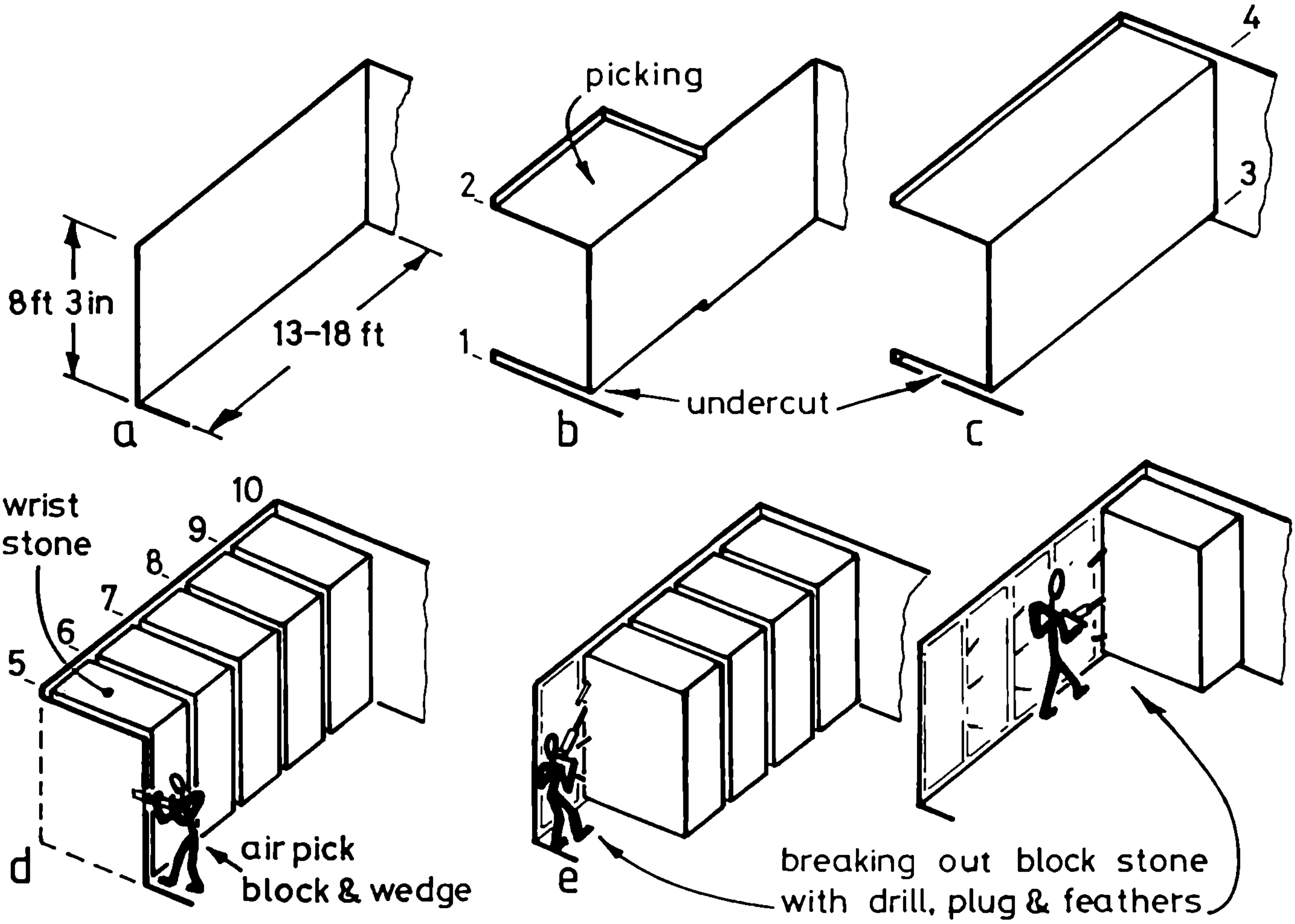
The same method was used in the Clift Quarry from the late 1950s, but here three compressed air Hardiaxe picking machines did the picking. The era of hand sawing came to an end when this quarry closed in 1968.



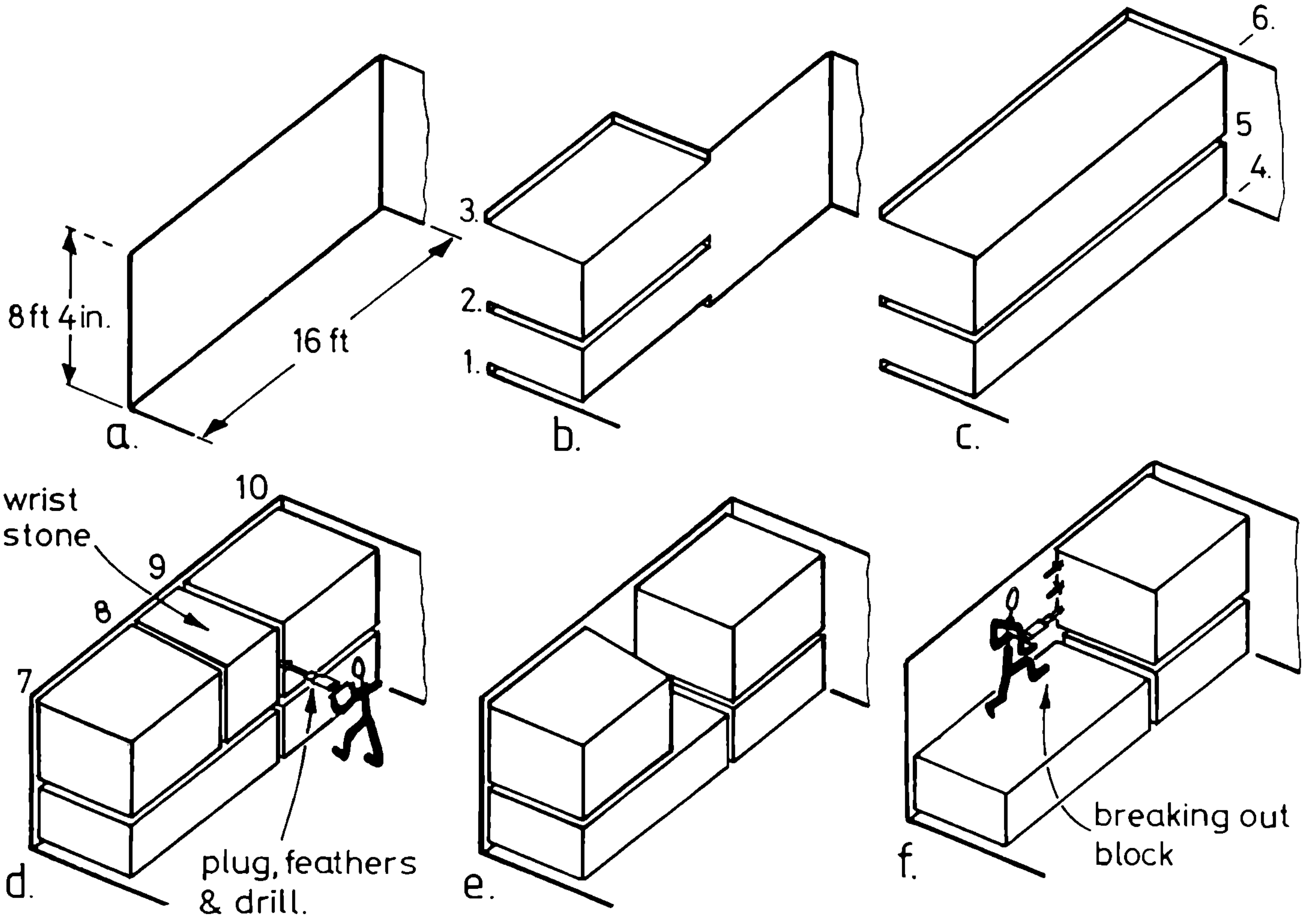
Plug & feathers

In 1974 the Tump Quarry at Westwood reopened, and a Samson Arc Shearer transferred there thus leaving one at Monks Park. At Westwood the beds of stone are about 8 feet deep, therefore the Samsons undercut, then cut the picking jad and finally vertical cuts are made at about 2 ft. 6 inch intervals across a breach of 13½ to 17½ feet. The wrist is then wedged off sideways using an air pick, wedge shaped drill bit and a wide steel wedge block to fill the 4½ inch wide saw cut. Depending on circumstances the other stones are got by this method or by drilling at the back and splitting off with plugs and feathers. To reach the picking the Samson is driven on to a wooden ramp.

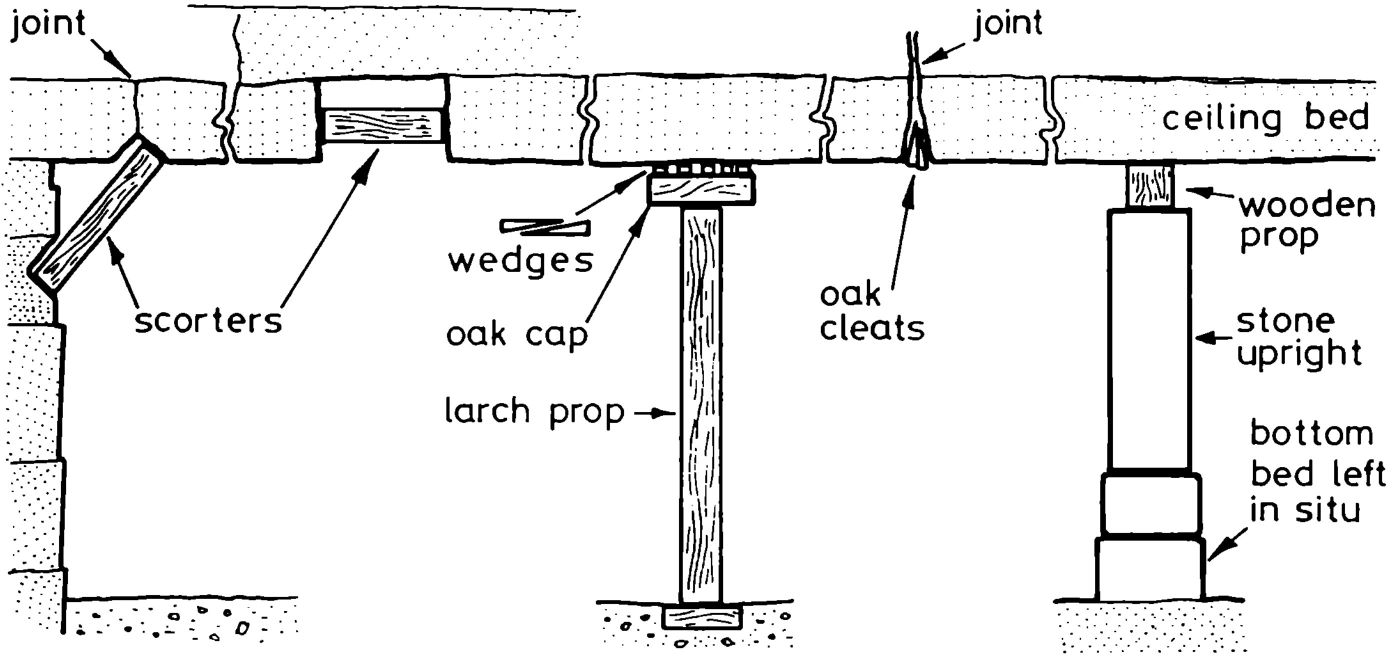
The upturn in demand for stone in the 1970s created a need for more cutting machinery. In 1979 the French firm Aubertin & Perrot supplied a rock cutter type VMC No 12921 to Westwood, however this machine, despite modification was unsuccessful and did little if any work. Hand held Vamo electric chain saws from the same source were successfully introduced at Monks Park in the early 1980s and relieved the pressure on the Samson at Monks Park for a while.



Westwood. underground quarrying with arc shearer.



Stoke Hill. underground quarrying with rock cutter.



Ceiling support: common methods.

Efforts were then made to find alternative rock cutting machinery or more Samsons, this lead to the purchase of some ex colliery Dreadnought Arc Shearers. The Dreadnought is a later and larger development of the Samson, made by Anderson Boyes Ltd of Motherwell.

During 1985 three Dreadnoughts were modified for quarrying at Monks Park by fitting a 15 inch spacer between the body and the chassis to enable the jib to pick at a higher level. As a result of this the jib can not undercut, thus Dreadnoughts are not suited for quarrying at Westwood.

Some hand tools can still be found at Monks Park and to a lesser extent at Westwood; lewises are still used for lifting stone and for anchoring snatch blocks to the quarry wall to enable a crane cable to pull around corners. To resist the crane cable 'snatch', these modern lewises are much bigger than those used in the past, the lewis hole is now made with an air pick but finished with the traditional holing iron.

The quarrymans pick still sees very occasional use for chipping down a face to locate the parting between the beds and jumper bars can be found in some working headings.

In 1982 a new company The Bath Stone Company Ltd reopened Stoke Hill and Hayes Wood Quarries. At first only the floor of the quarry was dug, this bottom bed had been left in situ because it was too hard to saw by hand. This bed is marketed as Stoke Ground because it is a good weather stone and is dug by drilling and splitting with plugs and feathers.

In 1988 the company took delivery of an Aubertin & Perrot Vamo chain saw rock cutter mounted on a Linde fork lift truck to pick the top bed which is about 6 to 7 feet deep. As built this machine was unsatisfactory, it was then rebuilt by a company in the Anderson Strathclyde group and performed very well. Anderson Strathclyde PLC incorporates both Mavor and Coulson Ltd and Anderson Boyes Ltd.

As a result an improved but similar rock cutter was ordered from Anderson PTT, as with the French machine cutting is by diesel hydraulic power.
A third cutter was designed and delivered by Anderson PTT in 1990, this one differs from the other two in that the vehicle and cutter are an integral unit, also 440V 3 phase electric power drives the cutter, diesel power is used to move it around the quarry.
The method of picking out the deep top bed at Stoke is similar to French practice, three horizontal cuts are made in the breach, under cut, middle cut and ceiling cut, then four vertical cuts are made between the ceiling and middle cut. The first and fourth cuts form the sides of the breach, the second and third are the wrist cuts in the middle of the breach and about 2 feet 6 in apart. The wrist stone is broken off and removed with a Hyster fork lift truck, the two stones each side of it are then drilled at the back, split off with plugs and feathers and removed by fork lift truck. At this stage a vertical cut is made between the and the undercut, drilling on the back frees these two stones and as before they are removed by fork lift truck. This method produces very uniform blocks with little wastage.

CEILING SUPPORT

Ceilings are supported by leaving pillars of unhewn stone, however local areas of weakness are supported in other ways usually by props or 'sticks'.

The most common prop is the 'scorter', these tend to be short and fit diagonally between a seating scored or picked in a wall and another in the ceiling. The exact length and squareness of the ends is critical, they are sometimes tightened with an oak wedge, but in years gone by a broken chip was often used

Upright props are less common as strength diminishes with length, a 'cap' made of a flat block of oak is fitted between the prop and the ceiling.

A common method of keeping a ceiling tight where it is traversed by joints a few inches wide is to drive oak wedges usually in pairs into the joint, these wedges are known as 'cleats'.

Horizontal timber at ceiling level is rare, there is one in the Cathedral, some at Lucknam and several in a pre 1840 quarry at Bradford on Avon where cross timbers were the only effective way of supporting a broken current bedded ceiling.

Larch is now the preferred timber for props; commercial growing of Larch started in this country after 1862, thus other timbers were used before.

Drystone pillars, walls and arches can be found in many older quarries.
At Godwins Quarry there are several examples of stone and wood supports, these consist of one or two long upended stones with a short thick prop on top, no doubt this was more effective than a long stick and in the quarry stone was cheaper than wood.

LIGHTING

Tallow candles were used for lighting in Bath Stone quarries until about 1870 when small tinplate benzoline lamps became popular, apparently on the grounds of cheapness. Quarrymen also made their own lamps out of a tin with a gutted bicycle tyre valve and wick fitted in the lid, the contents of cotton wool and paraffin gave a rather smoky flame.

Between the two wars acetylene lamps were slowly adopted. After the war Wolf type 60A acetylene lamps were supplied up to 1952. Both Monks Park and Westwood Quarries now have 110V electric light bulb installations and powerful spotlights are used in working headings. At Stoke Hill Oldham Crompton cap lamps are now worn.

ACKNOWLEDGEMENTS

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APPENDIX 1

PLANT & EQUIPMENT AT MONKS PARK QUARRY ca. 1965

SURFACE

Electric 6 ton winch by J Smith, Keighley; new 1951.
Electric 7 ton Derrick crane by Anderson Grice; put up 1951.
Electric 8 ton Derrick Crane by Morgan No 18; put up 1952.
Electric 8 ton Derrick Crane by Morgan No 19; put up 1952.
25HP Diesel locomotive by Ruston Hornsby; new August 1953

UNDERGROUND

3 - Pneumatic picks by Atlas Copco type KV 434B; new 1956.
2 - Pneumatic rock drills by Atlas Copco type RH 571 3L; new 1956.
1 - Pneumatic drill by Holman Bros. type SL 9; age unknown.
1 - Pneumatic ceiling drill with ram by Atlas Copco; new 1957.
3 - 60HP electric Samson coal cutters by Mavor & Coulson, Glasgow.
  No 6065 new Feb 1948.
  No 6066 new March 1948
  No 6067 new March 1948
1 - Electric 2 stage compressor, Atlas Copco Type AR3; installed July 1956
1 - Electric compressor, Ingersoll Rand Model 75C type 40; new Nov. 1956

3 - 7 ton Electric extending cranes by B & P Plant Hire 1948 & 49.
3 - 5 ton Electric extending cranes by B & P Plant Hire 1948 & 49.
5 - Air motor cranes by Perox Engineerng Ltd. new 1958.
1 - Air motor stacking crane by Wessex Machine Tools; new 1958.

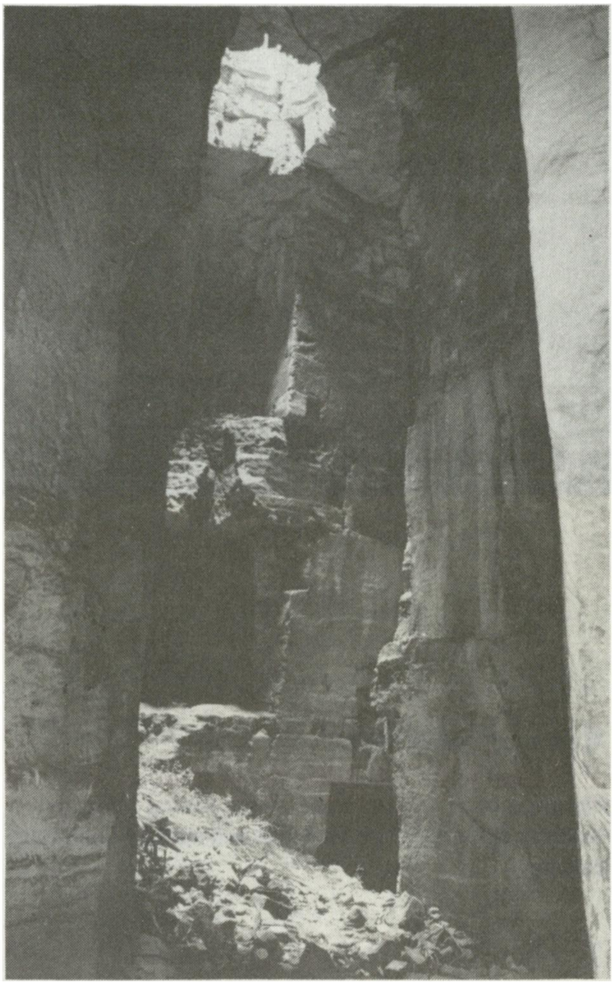
1 - 16HP Diesel locomotive by Ruston & Hornsby.
1 - Battery electric locomotive by Greenwood & Batley

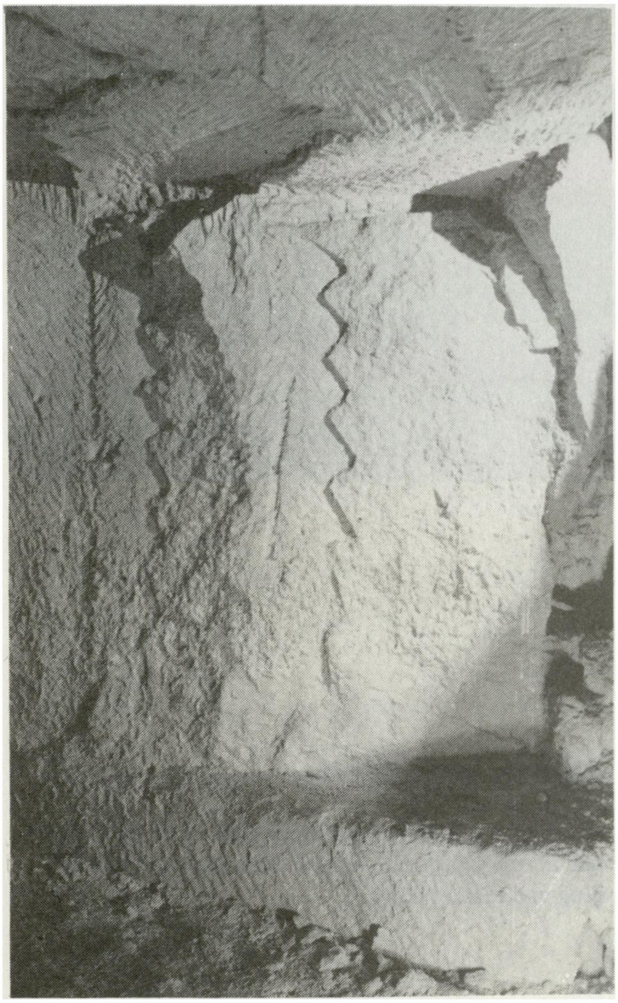
RIGHT

"The Cathedral" at Box Field Quarry, 1829 - c. 1850.

Note winding shaft in the ceiling and rope grooves around shaft hole and at bottom right.

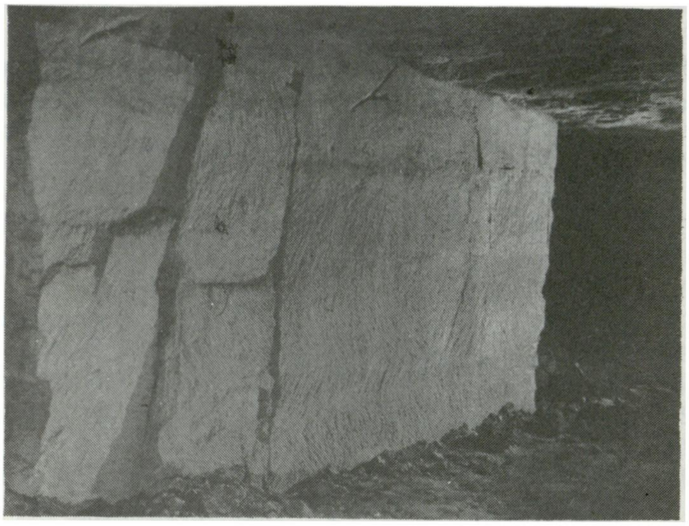
The upper levels linked up with another large chamber which is now filled in.





LEFT
Westwood. Godwin's Quarry

Evidence of splitting and wedging and wedging stone sideways off bed. Note joint on right hand sidc and shallow picking jad. Bottom bed left in situ at side of roadway

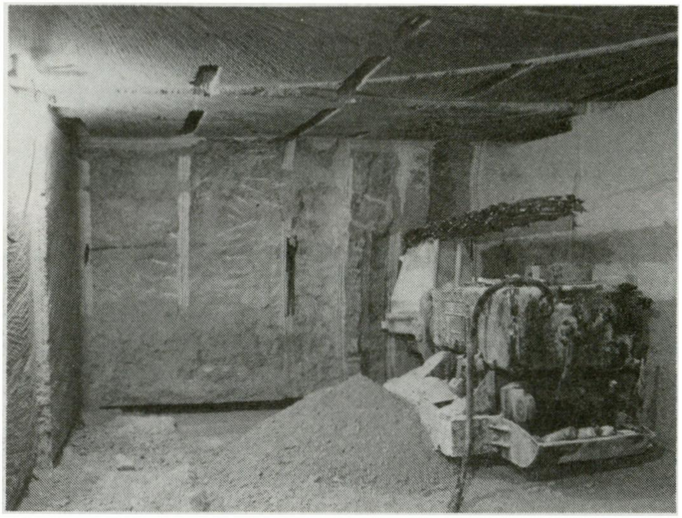


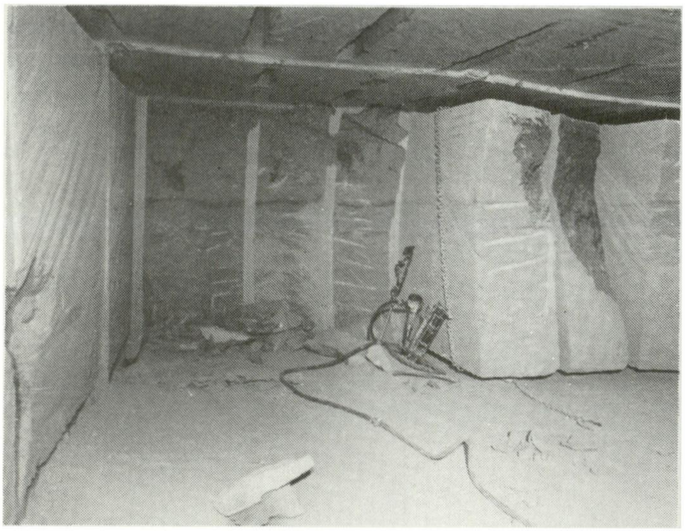
Box Field Quarry 1829-c.1850

Jadded wall. Note tooling marks made by pick and jading iron.

Westwood Quarry 1991-2.

Sampson 6067 on right hand . Note cutting jib in non-working position. Note undercut and marks of previous cutting.





Westwood Quarry 1991-92.

Heading with blocks partly removed. Note Atlas drills and air pick; picking, vertical cuts, undercut and split plug and feather holes.